The Influence of Woven Stretch Fabric Properties on Pattern Design

By

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Conventional pattern construction and pattern making methods typically require the size measurements of a range of standard mannequins or human bodies in order to construct the varying pattern blocks for garment design. These various methods and skills, in the fashion industry, factory or studio are performed by pattern makers or producers, and are refined through the garment sampling and wearer trial system (an uneconomical trial and error) used on woven garments or on woven stretch garments to produce varying garment designs. This is particularly true when fabric stretch and recovery properties and values are encountered. There is a strong alliance with the heuristic knowledge.

The aim of the present work is to investigate the influence of woven stretch fabric properties on pattern construction. The stretch and recovery properties of woven stretch fabrics will be taken account for pattern reduction and alteration for the development of a suitable garment pattern to fit the body shape and to meet the comfort requirement during the body movement. The relationship between the degree of alteration and reduction and the relevant fabric stretch properties is to be established.

In this thesis, the stretch and recovery properties of various woven stretch fabrics have been measured. The conventional pattern is reduced and altered based on the comfort requirement for body movement, fit to body shape and the extension and recovery properties of the woven stretch fabric. Wearer trial test of the altered garment pattern of woven stretch fabrics is carried out for subjective and objective evaluation in the reference of the traditional woven garment pattern. Their comfort and garment appearances are evaluated by a panel of judges and the wearer. The size and shape stability of garments after the wearing tests are assessed. The results demonstrated that the new pattern method was significantly better for woven stretch fabric. The garment pattern for fit and comfort can be predicated and produced according to the extension and recovery properties of fabrics.

The work described in this thesis is

the author's own,

unless otherwise stated, and it is, as far as she is aware, original.

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To my parents,

With love and thanks for their support and encouragement

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INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1. The Introduction of Woven Stretch Fabrics Containing Elastane Fibre

During recent years, the demand for more comfortable, convenient and versatile clothing is continually growing. Woven stretch fabrics containing elastane were introduced for making garments to meet consumer needs such as durability and comfort in movement, because they give good stretch and recovery properties. The extent of these properties will depend on the amount and type of elastane fibre incorporated and on the construction of the woven fabric. Stretch has an obvious impact on comfort, adding flexibility and more freedom of movement. But recovery is even more important for remaining garment shape. However, apart from adding comfort and fit through stretch and recovery, it can also offer lasting good looks, better drape, and easier construction in garment manufacture, as described below.

- long-term garment shape retention
- the characteristic resilience is increased
- comfort is combined with vitality
- elastane improves its product properties
- optimum fit
- moderate silhouettes and good comfort properties
- light fashion garments with good elasticity
- new styles and flexible design
- new surface structures
- three dimensional relief effects

- futuristic design for widening the fashion potential
- it gives woven fashion apparel a new dimension
- there is more freedom of movement and clothing is more comfortable
- there are more forms and structures, but less pattern constructions

Widespread use of woven stretch garments in the industrial sector provides a need for semi-automated processes for acquiring complete databases of each fabric extension level and garment pattern model for garment designs in digital form. At the same time, social, industrial, and economic changes mandate a need to increase productivity in the manufacturing sector, improve levels of quality and reliability in the finished product, and provide better tractability of parts going into the product being manufactured for product-defect liability aspects.

1.2 Current pattern design and construction for woven stretch garments

Using the conventional method to produce woven stretch garments, the garment has to be sampled and given a short wear trial, then washed or dry cleaned, before the pattern block is finalised for cutting. Each pattern block should be prepared individually according to fabric stretch and recovery properties and this is often a matter of trial and error (Disher, 1980). This has restricted the spread of semi-automation mainly to reproducible and repetitive tasks, working with fabric of good and consistent quality, or to those where variations are closely controlled and the necessary feedback of information from the process is of a fairly simple kind.

In a review of pattern development of woven stretch garments there is no reference directly for this area since the 1960's when elastane fibres were first produced. The nearest reference in 1996 (Aldrich and Aldrich, 1996) discusses the woven stretch pattern making methods still dependant upon manual and subjective methods. The fabric extension level is obtained from hand-stretch or a simple load-extension tester. Aldrich and Aldrich state that a neater body fit can be achieved by using the following formula:

1. Reduce the pattern by 5% in all horizontal measurements for every 10% visual stretch measurement.
2. Increase the vertical measurement by 2% for every 5% where the fabric is under tension.

This is a serious inattention to the production of woven stretch garments by using those measurements and methods subjectively.

1.3 Aims and Objectives

Conventional pattern techniques provide a reasonable means of reduction and modification, but their effectiveness and accuracy are very low, too subjective and can not produce the different garment styles and/or shapes in use of the same woven stretch fabric shortly and scientifically. This is mainly due to the complexity of the fast changes in both fashion cycle and material publication.

Aims

The main aim of this research project is to develop a new method for garment pattern construction for woven stretch fabrics rather than doing repeated garment sampling and wearer test process (try and error). The new designed (or altered) pattern will fit the body shape and also reserve comfort for the wearer's dynamic movements. This new method should provide the fashion industry and customers with a more flexible and efficient method of pattern production for woven stretch fabrics. This will provide initial information for future automated processes, utilising complete databases for fabric extension levels and garment pattern models.

Objectives

(1) To study stretchability of various woven stretch fabrics in different test methods and determine their extension and recovery properties which can be considered for pattern reduction and alteration;

(2) To establish a technique for woven stretch pattern block creation / modification which will take into account fabric properties;

(3) To evaluate the pattern with an emphasis on visual appearance.

1.4 Summary of the Experiments Described in this Thesis

Fabric stretch and recovery properties are highly dependent on the combined characteristics of various and complicated elements of fabrics and components of fabrics. A range types of woven stretch fabrics were used in the present work. Their woven structures and fibre components were determined as described in Chapter 3.

In the experiments described in Chapter 4, an Instron Tensile Tester was used to determine the tensile properties of these woven stretch fabrics. Repeat measurements were carried out to obtain the extension and recovery properties of these different types of woven stretch fabrics. The results were evaluated to give a general database and better understanding of the influence of fabric structures and fibre components on the extension and recovery properties.

Because woven stretch fabrics were created to offer customers the opportunity to wear tailored fitted garments and still have comfort during body movement, Chapter 5 looks at the development of garment pattern construction for woven stretch fabrics to meet customer needs. Pattern alteration and development were carried out on the base of a tailored basic princess-line dress. The stretch and recovery properties of woven stretch fabrics determined in Chapter 4 were taken account for pattern reduction. Considering the requirement of body movement in garment patterns, five postures were defined for the different level of body stretch the specific pattern conversion method was used to generate the new patterns considering the individual postures of the body movements. The final pattern for a woven stretch garment is generated by alteration of conventional woven basic patterns either to fit the body or to meet the requirement of body movements.

Chapter 6 assessed the reduced and altered pattern block generated for woven stretch garment as described in Chapter 5. Evaluated results are provided to verify the developed methods, including measuring methods, wear trial tests and scanned / captured images.

2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the world textile industry today, woven stretch fabrics have a secure place, and play an outstanding role in terms of wear properties, comfort and functionality in the fashion sector. Most of the current methods of producing stretch fabric were developed during the 1960's, and by 1965 were in many commercial ranges shown at Interstoff. In the 1980's an increasing number of weavers have been showing woven stretch fabrics, firstly those in the USA, followed quickly by Germany, then by the whole of Europe. The current methods for creating stretch were fundamentally very much based on the same methods in the 1960's. The development of produced materials (e.g. elastane fibre, textured yarn) have improved the wear properties of fabrics many times over, creating a base for new products at the same time.

Woven stretch fabrics are limited in range to a number of basic constructions of fibre, yarn, and fabric structures which, in recent years, have been produced by many companies in the large commercial market sector, e.g. jeans segment (Levi's), men's suits (Marks and Spencer) (Du point Ltd., 1990 and Rudie, 1995). This has become important because of the increased interest in body fit and comfort. Because of its use over the last 30 years stretch can be perceived as more of a constant quality now than a fashion trend. It is becoming important to offer better fit and comfort for all wearers, not just the body conscious. The comfort benefit of woven stretch fabric is to produce fabrics that are easier to fit the real human body shape. Many techniques exist for dealing with the methods of designing and producing for today's woven stretch fabrics. These include fabrics which contain 2% to 8% (or more) elastane yarn in existing products, heat-setting texturised synthetic materials, and finishing processes to obtain the required 'piece goods stretch'. Garments made of woven stretch fabrics can be produced by draping the fabric on existing dress forms, reducing existing two-dimensional apparel patterns by body ease, or relating skin stretch measurements to fabric stretch. Merely reducing a pattern by body ease, without considering the stretch factor of each individual fabric, may distort the finished product in key areas, therefore the garments made of woven stretch fabrics have to be tested for their ability to fit the human body in a non-constricting manner while stretching to accommodate for body movement (Ziegert and Keil, 1988, Kirk and Ibrahim, 1966).

2.2 Development of Woven Stretch Fabrics

The concept of "Stretch" as a term applied to woven fabrics is still a fresh word in the glossary of fashion. Originating in Europe, where it began in skiwear it has advanced to be used in suits and jeans, etc., where the stretch concept is based on the idea of making garments that move with the body, rather than those that inhibit movement.

Woven stretch fabrics are not intended to create a fitted silhouette or a skin-tight look. What they intend to provide is less restrictive movement where a wearer needs it most i.e. across the hips, in the seat and at the knees, etc. In addition, woven stretch apparel is more comfortable, can fit better for a sleek look, retains its shape and also has greater resistance to wear in strategic areas than non-stretchable apparel. Shirts and jackets of woven stretch fabrics for example, will "give" across the shoulders without putting excess strain on the fabric; and this holds true in every area where the body bends, such as at the elbows and knees. Woven stretch fabrics can also extend the range of fit for each size of garment. This is not to imply that one size will fit everyone, but that each particular size can adapt to individual variations of body shape within that size. Thus, the garment can fit more customers. Woven stretch fabrics are produced by three fundamental methods. (Disher, 1980, Du Pont, 1990 and 1995)

1. Elastane content in fabric more than 2% (normally within the range of 2-8%) (Disher, 1980, Hathorne, 1964, Meredith, 1971, Du Pont Ltd., 1990, Rupp and Böhringer, 1999)
2. Heat-setting texturised synthetic yarn (Rao and Shah, 1973, Atkinson and Wheeler, 1996)
3. The finishing process known as 'piece goods stretch' (Kanebo Co., 1997)

From the construction of woven stretch fabrics it is apparent that the final properties of woven stretch fabric are mainly dependent on the structure of

1. The structure of stretch yarn
2. The amount of elastane used
3. The degree to which it is stretched during weaving
4. The construction of the fabric
5. The finishing treatment

Obtaining the desired extension level is essential for an efficient woven stretch fabric. However, the property of stretch is not enough. It is also necessary to design a fabric structure that has the ability to return to its original state, quickly and almost completely. This is very important for fabric dimensional stability and garment performance and can be achieved only when the selected yarns attain sufficient recovery forces. The recovery force, which is mainly dependent on the fibre and yarn structure, should be great enough to overcome the friction between yarns, returning the fabric structure to its original dimensions when the extension stress is removed.

2.2.1 Elastane Content in Fabric more than 2%

Producers have introduced an improved process for preparing a woven stretch fabric. This process is made up of weaving warp and weft combination yarns comprising a non-elastomeric yarn and an elastomeric strand which is a partially molecularly oriented synthetic organic polymer. The elastic strand has a heat-setting temperature that is higher than the heat-setting temperature of the non-elastomeric companion yarn. The woven fabric is treated by heat-setting at a stretched condition for 30-90 seconds (at least 20 seconds) at 120-180°C or more, and finished in an aqueous bath for ½ to 1 hour (at least 30 minutes) at a temperature no higher than 135°C (Du-Pont-de-Nemours-and-Co-EI, 1995, El-Du-Pont-Se-Nemours-and-Co., 1997).

Woven stretch fabric can be made with elastic yarn in both uniaxial and biaxial directions as shown in Figure 2.1 (Du Pont Ltd.). If it is used in the warp the fabric will stretch lengthwise. If the yarn is used in the weft, the fabric will be elastic in the width direction. The extensibility and elasticity of a woven fabric with elastic yarns is further improved by the fact that the combination yarns worked in the weaving process condense the fabric during the finishing process such as relaxing or shrinking processes.

The fabric appearance of a woven stretch fabric depends on the type and composition of the combination yarn, type and construction of grey fabric, and on the finishing conditions.

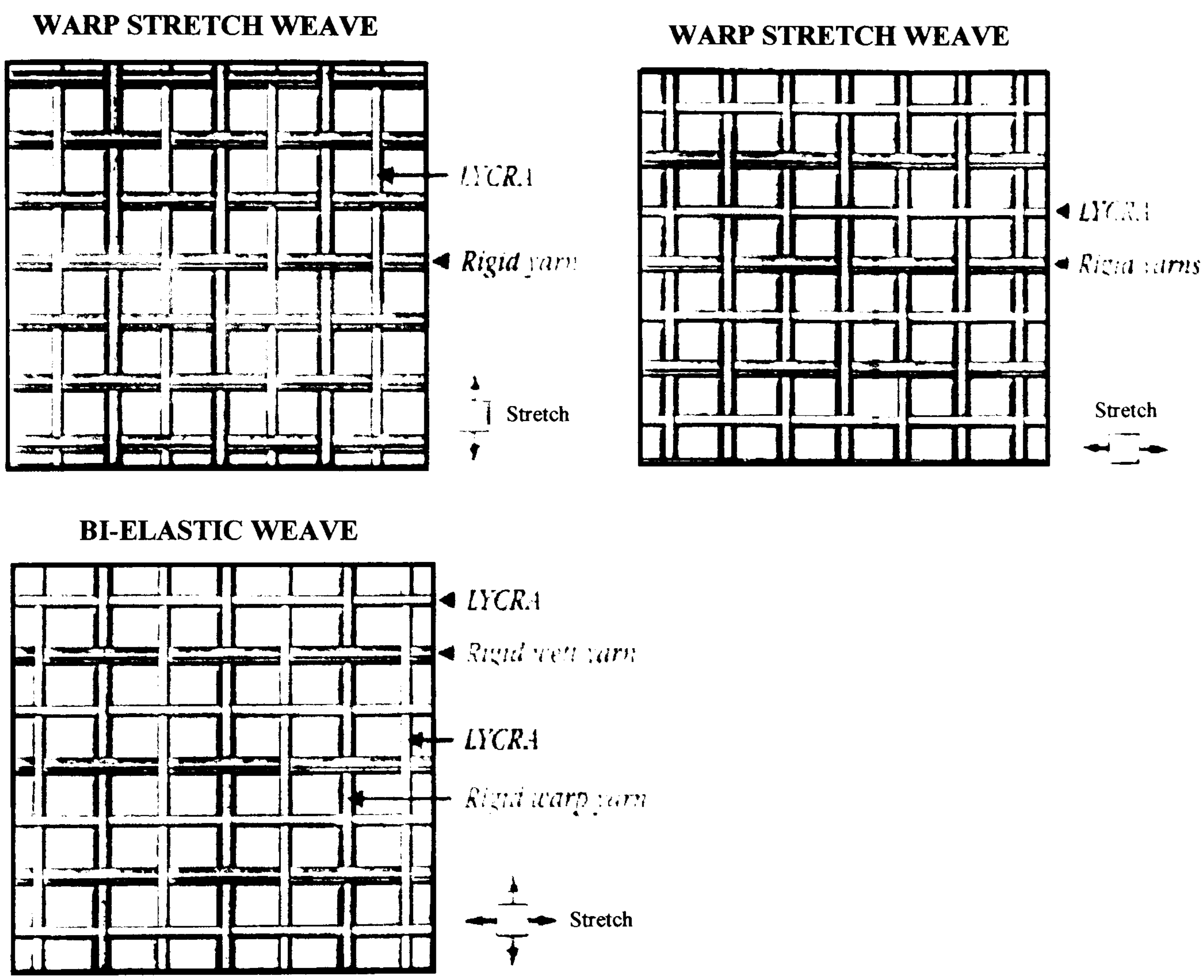


FIG. 2.1 Warp stretch weave; Weft stretch weave and Bi-elastic weave (Du Pont, 1995)

The elastane content, the type of combination yarn, the inelastic components employed, and also the fabric construction determines the fabric properties. The result of these factors is that different woven fabric types with identical extensibility may reveal a different load/extension characteristic, resulting in differing recovery powers.

2.2.1.1 Elastane Fibres

The basis for synthesising the polyurethane-elastomeric fibre found on the market today is the diiso-cyanate-polyaddition process developed by Bayer, Rinke and collaborators in 1937, with the aid of which linear, high-molecular polyurethane synthetic hard fibres were successfully spun. In 1939, Paul Schlack produced linear polyester, including adipic acid glycol polyester, with equivalent quantities of diisocyanates and obtained higher molecular compounds with fibre structures, including some with highly extensible and elastic behaviour.

In 1949, Windemuth developed a chemical spinning process in which chemical synthesis of the high molecular polyurethane is simultaneously effected, with stretch, into elastomeric yarns. Reactive spinning was studied for the first time in 1942 by Phol, and later used on linear and cross-linked polyurethanes. In 1951, Brenschede carried out the solution by spinning polyurethane elastomers of the Vulkollan type. The first process for the industrial-scale production of elastane fibres using dry spinning was worked out by Shvers and collaborators in the pioneering Research Division of E.I. Du Pont de Nemours & Co., Inc. (USA). Since 1962, this multi-filament has been in industrial-scale production under the name of “Lycra”. In 1964, Bayer AG (D) under the name of “Dorlastane” introduced a bonded multi-filament yarn to the market.

Today, elastane combination yarns are used for different fields of application, and always where:

- The required stretch effect can not be achieved with bright elastane yarn
- Handle and appearance are important
- Protection of the elastane yarn against extreme loading is of paramount importance
- Construction and processing technology require it

1. Structure:

The molecular framework of polyurethane elastane fibres is unique and remarkable. Very special structural geometry is required to cause molecules to recover well after being deformed to several times their initial length. Research on stretch fibres, dating back to the 1940s, showed that elasticity occurred when polymeric molecules contained two types of segments, one soft and deformable, the other hard and crystallizable alternating along the same chain.

Figure 2.2 (Du Pont Ltd., 1990) illustrates simply the network of such systems. The soft segments comprise the springs, tied into a network by molecular-sized aggregates of hard segments. Stretching the fibre straightens the coils. Since this stretching happens easily and a "soft" stretch results, useful for comfort in clothing. As the molecules straighten to a few times their coiled or crimped length, however, they begin to stiffen and even crystallise somewhat. In this way they reinforce the fibre, enhancing its breaking strength. When released from extension, they recoil forcefully.

In comparison, the molecular network of rubber is held together differently, with chemically bonded atoms cross-linking two chains at a time. In either system, if the springs fail to recoil fully or should slip their moorings, incomplete recovery or "set" will occur. Well cross-linked rubber has very low set. Polyurethanes are adequate in this property and they generally surpass rubber in power on an equal weight basis. Rubbers are made from natural plant milk or synthesised, which has good quality on elasticity to prevent abrasion and has softness ability, extensibility, and non-water permeability. It is always synthesised with yarn or textures to produce elastic ware, e.g. Raincoat, Tire. In 1930, synthetic rubber was created in the USA; presently it is usually used instead of elastane fibre. The elastane fibres (a) have elasticity and look like rubber material, (b) have very high extensibility at least 200%, regularly 500 ~ 800%, and (c) have good resilience, which gives comfort or formability. Although rubber filaments are highly elastic (i.e. they can undergo high extension and after the extension they show practically no residual extension) they have several serious disadvantages for application in textiles. Rubber has very low tensile strength and relaxes very slowly. To obtain a satisfactory elastic effect it is therefore necessary to use a higher weight percentage of thicker filaments in the textile. This is unsatisfactory for very finely woven fabrics. Typical properties of rubber and elastic fibre filaments are compared in Table 2.1. (Meyer, Haug, and Spolgies, 1994)

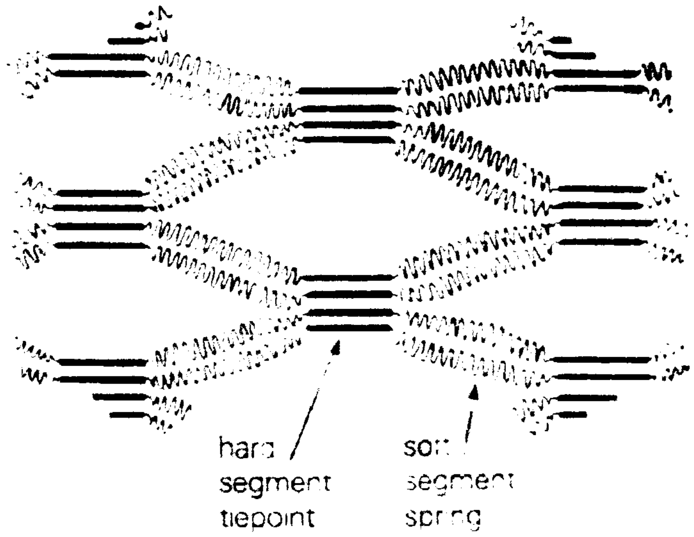


FIG. 2.2 The natural relaxed state of elastane fibres which include soft and hard segments (Du Pont Ltd., 1990)

Table 2.1 Property comparison: Elastane fibre / Rubber

Property	Rubber	Elastane Fibre
Tensile stretch (cN/tex)	3	9 ~ 13
Extension at break (%)	600 ~ 700	500 ~ 600
Modulus (cN/tex)	0.2	0.5
Residual extension (%)	3	20
Ageing resistance	bad	good
Dye-ability	no	yes
Finest titre (dtex)	100	11
Thermal moldability	no	yes

2. Definition:

Elastane fibres are synthetic fibres, which are built up of linear macromolecules. At least 85% by weight of their composition is segmented polyurethane. Elastane fibre, along with elastodiene fibre (synthetic rubber fibre), is included among the elasto-fibres (highly elastic fibre) group. This group includes fibres, which are extremely highly susceptible to deformation because of their chemical construction, i.e. they have an extension at break of more than 200%, and usually 400% to 800%, and return immediately and almost completely to their original length when the deforming force is removed. This definition excludes elastic textured yarns, which owe their elastic properties merely to a subsequent physical change in their spatial arrangement. Under the influence of ISO standard 1043, the West European man-made fibre producers combined into the BISFA (International Bureau for the Standardisation of Rayon and Synthetic Fibres), and agreed on a uniform designation. Since then, elastane has been abbreviated to "EL". Whilst elastane was used first of all merely as a purely functional special fibre in corsets, dressing and medical stockings as a rubber substitute (*), today's application range is very much larger (see Table 2.2).

* Typical elastane proportions:

Woven fabrics: 2-8%; Underwear: 2-5%; Swimming and sports products: 12-20%; Fine hose: 2-12%; Corsetry: 10-45%; Medical stockings: 35-50%.

Table 2.2 (%) market shares of most important producers in the world as regards capacity of elastane yarns (120 000 tonnes)

Brand Name	Company	(%)
Acelan	Taekwang (ROC)	13
Dorlastan	Bayer Faser GmbH (D)	9
Lycra	Du Pont Nemours (USA)	55
Roica	Asahi Kasei (J)	4
Glospan	Globe MFG Co.(USA)	4
Lineltex	Fillattice	-
EEY	unitika (J)	-
Texlon	Tongkook; ROK	6
Lubell	Kanebo Ltd. (J)	-
Mobilon	Nisshinbo Ind., Inc. (J)	-
Spantel	Kuraray	-

Source: P. -A. Koch Fibre Table, elastane fibres 1995, RWTH Aachen (D) Institute of Textile Technology

2.2.1.2 Elastomeric Yarn

This is based on the use of man made elastane fibres, for example Spandex. In woven stretch fabrics, other fibres or yarns, such as wool, cotton, linen, polyester and viscose usually cover the elastane fibre. The aesthetic and tactile qualities of the covered fibres can be improved, since the spun fibres remain on the surface of the yarn while the elastane disappears completely into the yarn as a core. Currently, it is the most popular method used to achieve stretch properties in this kind of woven stretch fabric. There are several types of elastomeric yarns of which four are discussed below.

1. Bare Elastomeric Yarn: bare elastomeric yarns, usually composed of elastane fibre, are used for power stretch textiles. These have softer properties than covered elastic yarns and moderate resilience. Elastane is rarely used in the original state, i.e. "bright" or "bare", but is further processed into yarn by various techniques, the finished textile consisting of a two-component yarn, the core consisting of the extensible elastane yarn and mantel, or the core wrapping, with fibre material like cotton or wool. In the case of bare elastomeric yarn, the producer must select a denier high enough for good power in the fabric but it is possible to minimise this denier, and hence costs.

2. Covered (Wrapped) Yarn (single, rarely doubled) (Du Pont Ltd., 1990, Rupp and Böhringer, 1999): This is composed of elastane fibre, which is covered or convolved (twined), around a spun or filament yarn. The elastane is wrapped inside, and is used for power stretch textiles. It is denser and has a higher extensibility to keep shape better than bare elastomeric yarns. Open constructions, such as women's tights, will not permit jamming of the fabric.

Here a ‘ covered’ yarn is used. An inelastic yarn is wrapped around a core of elastane fibre, as shown in Figure 2.3. As the yarn retracts, the covered yarn jams together and holds the core yarn in an extended state. Most wrapping is done with continuous filament yarns on high speed winding machines. Staple (‘cut’) fibres twisted around a stretched elastane fibre will prevent it from retracting fully and so give an elastomeric yarn with good stretch properties.

3. Core Spun Yarn: an elastane fibre core is covered by staple fibres. These yarns have very low resilience and they can be used for stretch textiles where comfort is important. It is spun into a very fine lean yarn. Core spun yarns are knitted or woven directly into stretch fabrics. Whether the elastane fibre is held extended by jamming of the whole fabric or of its yarn components. The unfinished knitted or woven article often contracts and becomes narrow due to the fabric construction, if so, the finisher stretches it on a setter to the desired width and passes it through steam or, more commonly, dry heat at around 200 °C for a few seconds. This heat setting relieves excess retroactive force without damaging the elastane fibre. It stabilises the width and so limits the available fabric stretch, as shown in Figure 2.4 (Rupp and Böhringer, 1999).

4. Bi-component and Bi-constituent Stretch Yarn: This is produced from stretch elastic filament fibre and is used for comfort elastic textiles. Elasto-twist yarn shown in Figure 2.5, DD ply yarn (double twist), Sirospun yarn and Blown yarn are also kinds of elastomeric yarns. A suitable machine for the production of mantel yarns is the “Elasto-Twister” manufactured by Hamel (a member of the

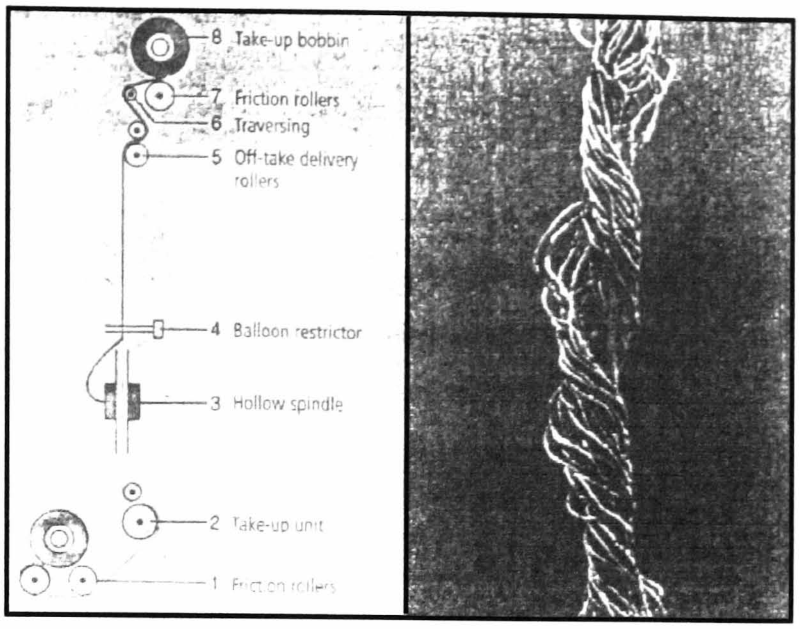


FIG. 2.3 Simple wrapping process and the illustration of single-wrapped yarn

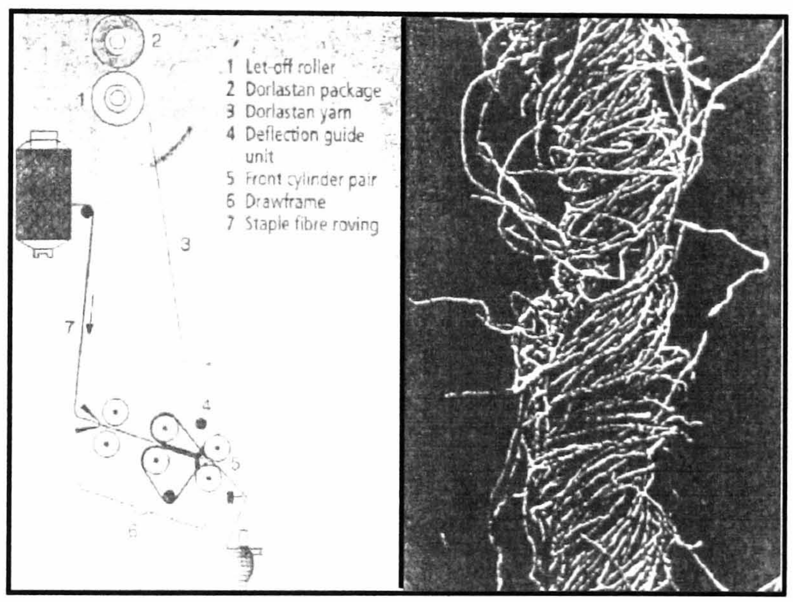


FIG. 2.4 Principle of core yarn production and the illustration of core yarn

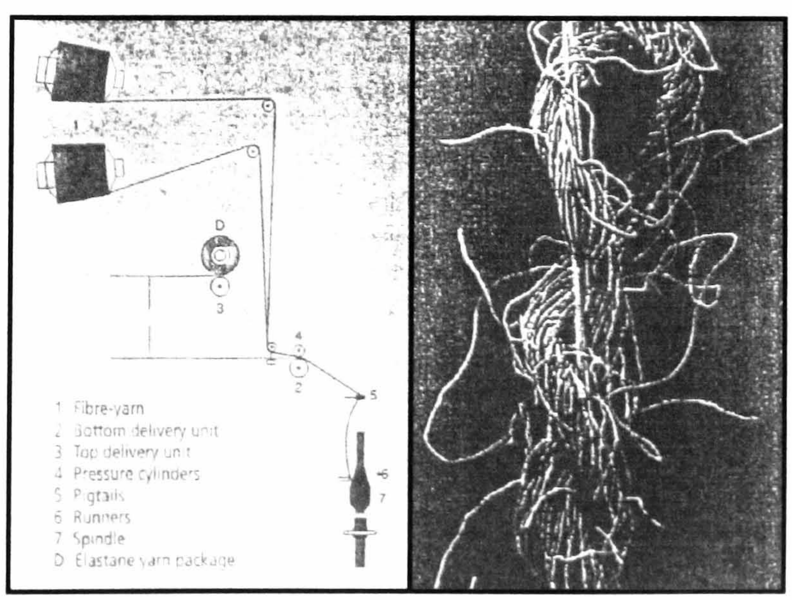


FIG. 2.5 Schematic diagram of a ring doubler with additional delivery unit and the illustration of a ply yarn

Swiss Saurer group). In this process, an elastomeric core is wrapped with staple or continuous filament yarn in the 15-270 Nm count range, the elastomeric yarn remaining free of twist, and being completely covered by the mantel yarn. Elastomer and wrapped elastomer of widely differing yarn counts can be used for the elastane core.

A leading manufacturer of machines for wrapping elastane yarns is ICBT Roanne, a member of the French ICBT group. The company offers three systems - conventional single and double wrapping and the air process are shown in Figures 2.6 and 2.7.

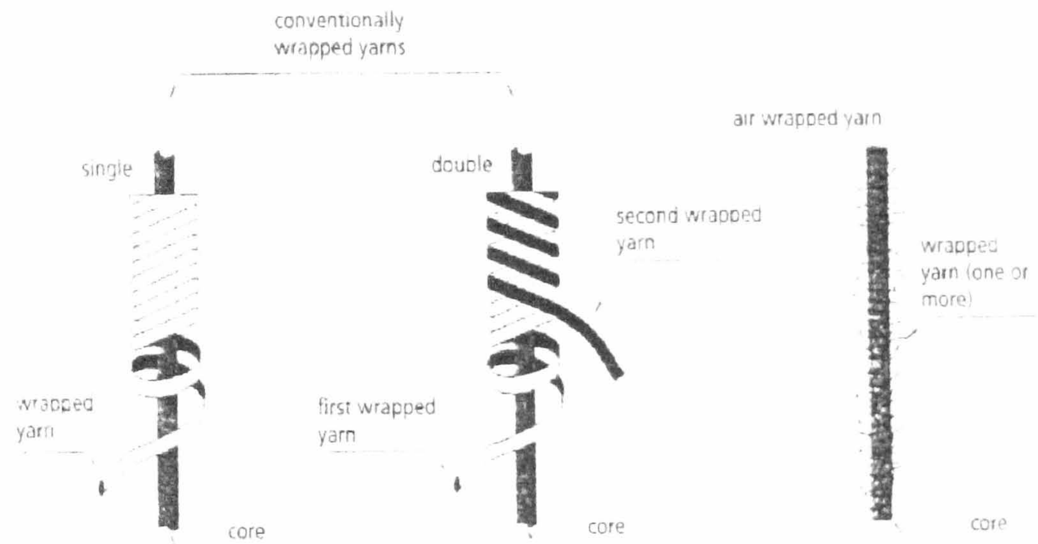


FIG. 2.6 Schematic diagram of yarn wrapping.

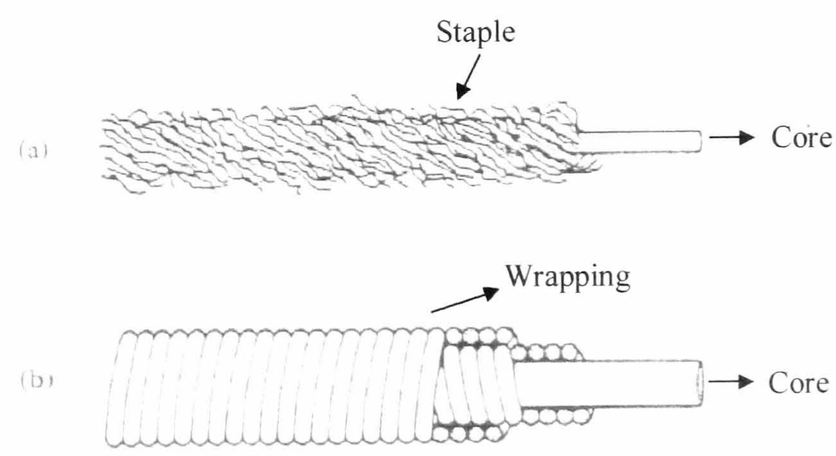


FIG. 2.7 (a) Core spun yarn; (b) Wrapped yarn

2.2.2 Heat-Setting Textured Synthetic Yarn

This method is used to give man-made filaments of polyester or nylon stretchability through deformation and heat setting. These texturised stretch yarns can be used in either the warp or the weft of a woven fabric to develop stretch properties in either or both directions. It can impart a warp or weft elongation of 15 to 20% to the woven fabric. But the recovery of such fabrics is not always satisfactory and may decrease as a result of material fatigue during wear.

Textured yarns are continuous filament yarns usually of nylon or polyester which have been manufactured in such a way that distortions are introduced along the length of the filaments. If these distortions or crimps are of the right form, the individual filaments act like springs and thus provide the yarn with a considerable stretch and recovery potential. Figure 2.8 (Denton, 1973) shows textured yarn in an extended and a relaxed condition. A combination of yarn and fibre crimp provides stretch of textured yarns but when extended most of the extension originates in the yarn extensibility derived from the straightening of the filaments. There is little yarn crimp interchange.

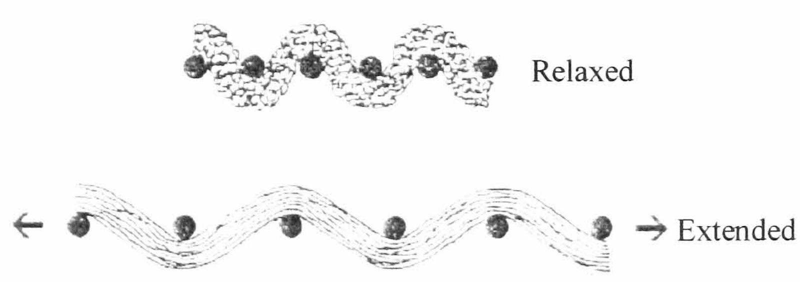


FIG. 2.8 Fibre crimp in a stretchable fabric made from textured yarn

There are three types of textured yarns: stretch yarn, bulked yarn and modified yarn.

1. Stretch Yarn: textured yarn is a kind of comfort stretch yarn and a continuous thermoplastic filament, which has very good extensibility and resilience after processing. Textured stretch yarns are produced by:

(a) Edge Crimping: when raw thermoplastic filament fibre under transition temperature status is passed (scraped) across a static knife-edge under tension. The side, which touches the edge, becomes compressed and bulked, and the other side of the yarn becomes elongated and bulked. The yarn is allowed to relax after scraping and becomes looped because the two sides of the yarn have different compression and elongated proportions.

(b) False Twist: this use the thermoplastic property to twist yarn in one direction after a heart setting process the yarn is un-twisted in the opposite direction. This increases frictional cohesive forces among the fibres and improves the bulk and stretch properties. False-twist crimped yarns are produced by conjugate spinning of polybutylene terephthalate and polyethylene terephthalate at a weight ratio in the range 30:70 in a side-by-side or sheath/core arrangement. The degree of crimpability and the conditions of single-heater false twisting are controlled. The yarns may be used to produce stretch woven fabric having a stretch of 15% or more (Kuroda, Ishii and Shibata, 1983).

2. Bulked Yarn: This has a higher bulked property and a lower stretch property. Bulked yarns are textured yarns, in which different kinds of processes can be used to improve the permanent distortion and degree of looped crimping shape. This kind of process modifies the surface structure and physical properties of

yarn. Bulked yarn has a higher bulked property, which influences the end use of textiles. Various types of bulked yarn are available, the bulked property of the yarn being more important than its stretch property. There are four kinds of processes: (a) knit-de-knit, (b) stuffed-box texturing, (c) air jet texturing and (d) twist texturing processes. Bulked yarns are not the focus of this project, which just targets stretch materials.

3. Modified Yarn: this type of yarn utilises a heat-setting process, which makes the yarn more stables and reduces extensibility. It is made from long-chain polyester fibre. It can also be produced by passing it through a steam heat-setting machine then finishing, producing a "set yarn". A modified effect can also be achieved during the process of yarn dyeing.

2.2.3 The Finishing Process known as "Pieces Goods Stretch"

100% cotton and cotton blends and also 100% wool are shrunk without tension in a bath of sodium hydroxide solution, as normally used in cotton 'slack mercerising'. 100% wool fabrics are also given stretch properties by crimp interchange. The warp is stretched to the point where the width of the fabric is narrowed. As a result, the normal weaving crimp, which existed in the warp, is transferred to the filling. In that stretched position the fabric is set by heat (i.e. weaving with a very tight warp so that the weft threads crimp themselves during the weaving process). This method is often referred to as mechanical stretch and it can be applied in either the warp or the weft direction and achieves only limited stretch properties about 10-15%. In addition, the stretch can not be reproduced with the required degree of accuracy. The Ex. Kanebo Spinning

Corporation has developed Technofit, a 100% cotton stretch woven fabric. Technofit has stretchability of 15-20% and fits to the body. It is based on regular 100% cotton grey fabrics and is made by proprietary high-pressure scouring and mercerising, and a new way of finishing. It can be coated, and there is no restriction on manufacturing and processing compared with fabrics made of polyurethane yarn. (Kanebo Co., 1997)

Figure 2.9 (Denton, 1971) shows the cross-section of woven fabric. The crimped weft yarns run crimped around the warp yarns in the relaxed fabric. When the fabric is extended in the weft direction the warp yarns move up and down relative to the weft and become more crimped whilst the weft becomes less crimped. Yarn crimp provides stretch potential. Mercerising cotton fabrics with no restraint in the weft direction but with a high warp tension can make fabrics of this type. This gives the required maximum crimp in the weft and minimum in the warp. Mercerising causes the crimp to be set into the weft more or less permanently and after stretching it is the set crimp which provides the recovery property.

1. <u>Slack Mercerised</u>: Slack mercerised yarn is where the yarn or fabric mercerised in a relaxed condition. The crimped yarns could be pulled back, and can be relaxed therefore offering elasticity. Slack mercerised processing can also be used on finished woven fabric (becoming stretch woven fabric). This technique is especially suited to mills that work with cotton for the development of stretch in the 15% to 20% range in a broad weight range. Crimp interchange gets its name from the application of tension in one fabric direction (crimp less than 1%) while allowing the other direction to relax and develop (by transference) a high crimp. Crimp interchange clothes can be made with many different kinds of yarns. Blends are important in developing stretch recovery but if slack

mercerisation is employed, 100% cotton is usually used. Polyester / cotton blends are probably the best yarns to use but polyester components require careful selection (Seidel, 1980).

2. Mechanised: Fabrics are formed under tensioned condition and are relaxed from this state to provide the potential to stretch. The relaxation is taken up in the fabric by distortions or crimps which appear in the materials making up the structure. These crimps may appear in the yarns, in the fibres, or in the molecules making up the fibres. Recovery forces must be directed along the stretch direction to ensure optimum snap-back and minimum residual extension.

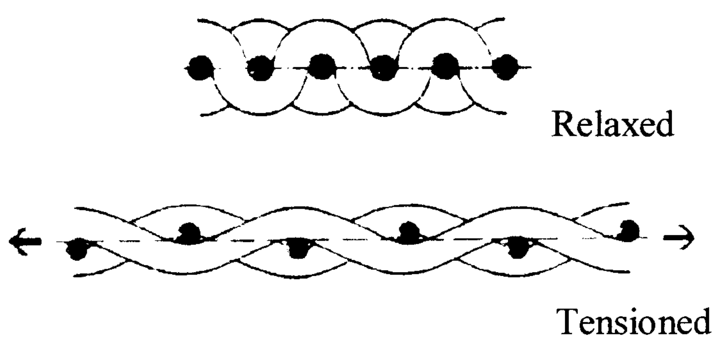


FIG. 2.9 Interchange of crimp between warp and weft yarn in a weft stretch fabric

Today there is at least one new method through the very recent introduction of a bi-component polyester fibre which is claimed to give a wool-like crimp to produce stretch properties in a fabric woven from spun yarns rather than filament. It is generally an intimate blend with worsted or viscose (but not intended for 100% polyester spun yarns), used in the warp or weft, or indeed both. The 'comfort' fabrics which range from shirting to suiting need to look exactly like their non-stretch equivalent and the elastane fibre must disappear completely into the fabric's surface, whether it is gabardine, crepe or poplin. Moreover, there is no real technical ruling as to whether, from a garment maker's point of view, the stretch should be warp-ways or weft-ways and bi-axial. Again, the degree of stretch for different end uses is thought to be 20-30% for tailored clothing, 25-40% for casual wear and 40% upwards for active sportswear. Figure 2.10 shows that only elastane fibres make it possible to produce over 30% stretch. Other processes cannot duplicate these stretch effects. Many reports deal much more extensively and intensively with this topic. (Rupp and Böhringer, 1999 and Meyer, 1994) They have tried to show the technical possibilities of producing stretch fabric, but the stretch fabric market undeniably belongs to elastane blends. The preferred process option depends on the question of how much stretch a fabric must have. The stretch woven fabric concept first found its most important end use in ski-pants made with Helanca (a trademark of Heberlein, which was the first nylon stretch yarn introduced in 1947). The elastane yarn has developed into tailored apparel and manufacturers are taking advantage of benefits such as comfort, fit, improved appearance, the drape and less wrinkling.

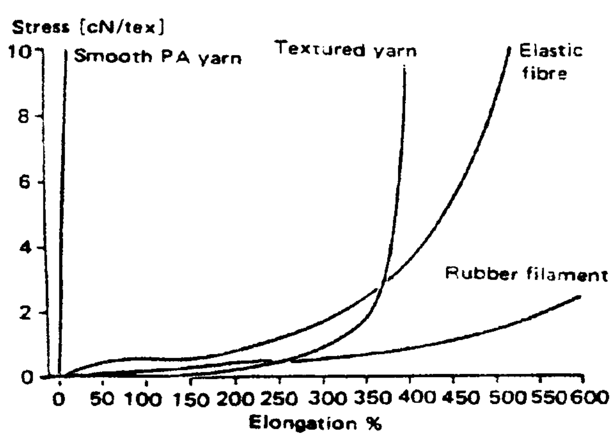


FIG. 2.10 Correlation between production process and obtainable stretch effects for certain applications (load / extension behaviour).

In recent years, designers seem to be more interested in the fabric's transforming qualities. There are a number of designers using woven stretch fabric not only for stretch, but also to keep the shape of the garment. However, some problems still remain in producing woven stretch garments. If the woven stretch fabric properties cannot be assured, it could affect its application to this apparel market.

2.3 Pattern Construction for Women's Wear

2.3.1 Introduction

Today most clothing is sized according to abstract increments related proportionally to a sample size. For much fashionable clothing this sample is developed by fitting the pattern to a fit model. Consumers who have different body types choose the most satisfactory size from those available. Thus many individuals with a variety of body configurations, body alignments, and body proportions must fit into any given size in the system of mass-produced clothing. For pattern construction the woven stretch fabrics have a significant or reasonable percentage stretchability to affect pattern change and allow pattern reduction and alterations. Du Pont's making-up Bulletin L-95 (Du Pont, 1995) stresses the fact that certain parts of the garment patterns should be made smaller when using stretch fabrics as shown in Figure 2.11. When fabrics containing higher percentage stretch are used the pattern must be slimmed down more than for those with a lower percentage and in all cases the garments should be sampled and given a short wearing trial, then washed or dry cleaned, before patterns are finalised for bulk cutting. Each pattern must be prepared individually according to the stretchability of fabrics, and this is often a matter of trial and error (Disher, 1980).

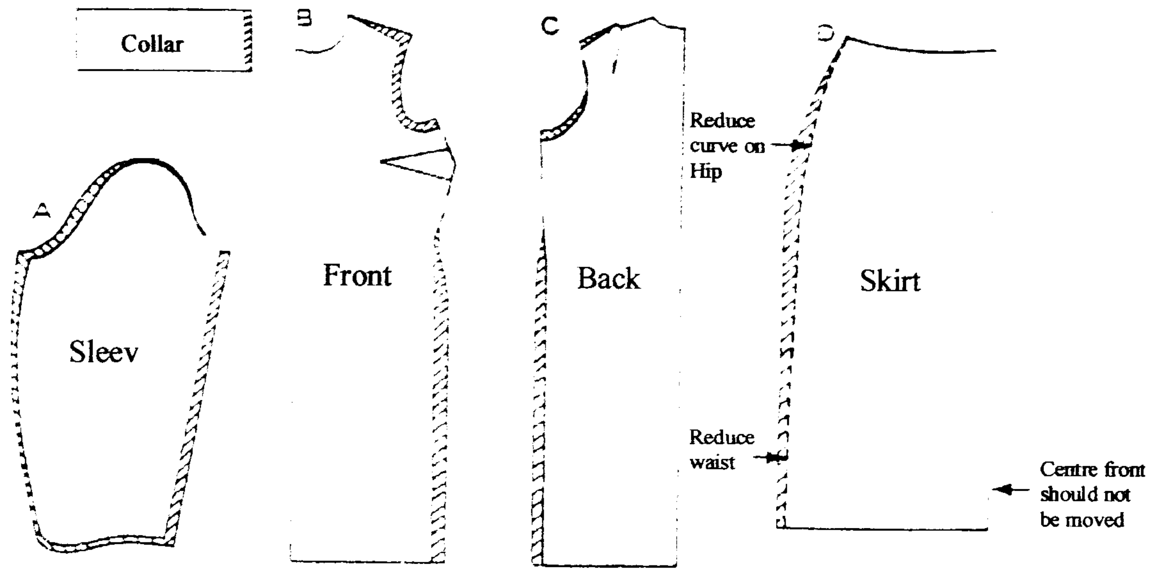


FIG. 2.11 In diagrams A, B, C and D, the larger outline and shaded section shows the standard jersey pattern. The smaller pattern in the section is used for the stretchable fabric. The stretchable dress was attractive and judged more comfortable by the wearer than the one made of non-stretchable fabric

2.3.2 The Course of Pattern Construction for Women's Wear

Over the past hundred years, industrial pattern constructions have evolved in an effort to keep pace with the changing silhouettes and fashion trends, as shown in Figures 2.12 to 2.14. The original constructions were complex and inconvenient. Special features can be incorporated in the construction upon request, such as ease. Each year the constructions are altered to reflect the current fashion silhouette due to the desired fit appearance of the final garment. Body measurements are a major factor in the development of the basic pattern block and are important because they:

- Serve as the foundation for pattern drafting, draping, and development of new designs
- Establish body dimensions
- Are a reference for pattern corrections

• Are a timesaving device only when taken accurately. This requires maximum concentration and patience throughout the measuring process.

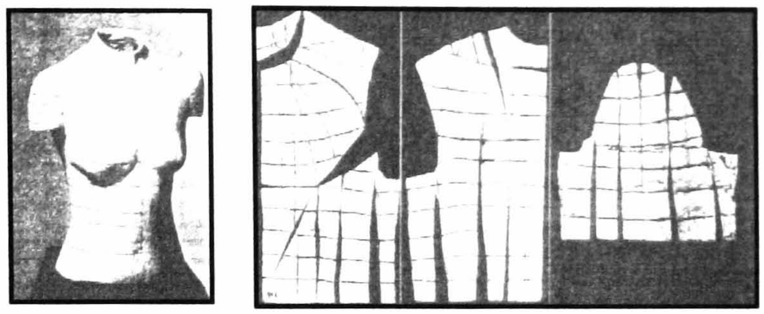


FIG. 2.12 A form of human bodies captured in plasterwork (Miyoshi, 1985)

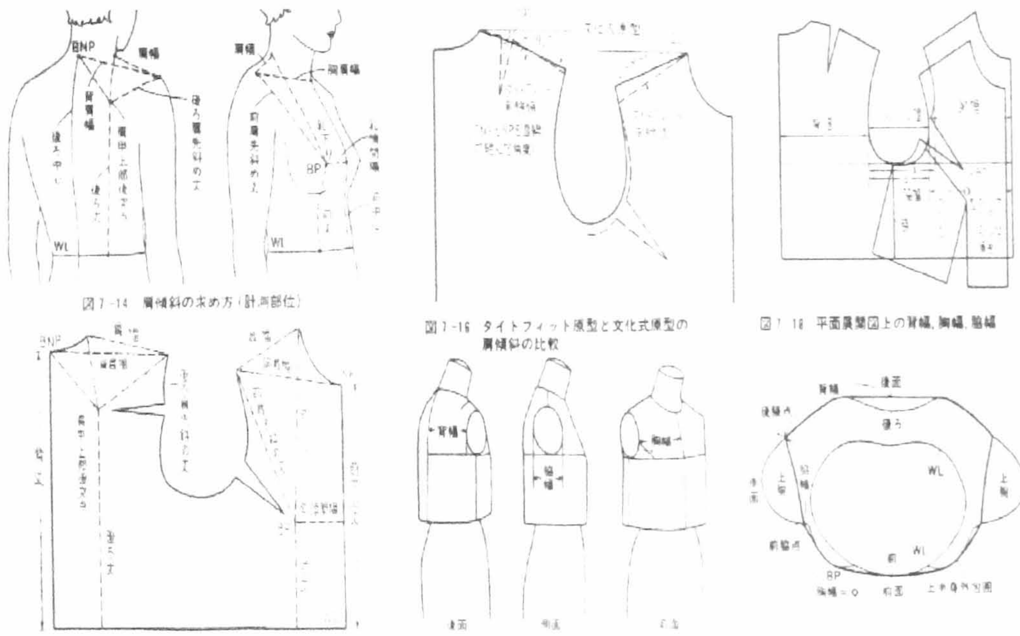


FIG. 2.13 An experiment in pattern construction

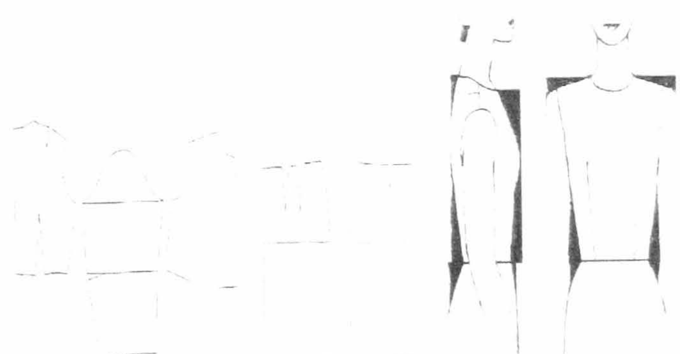


FIG. 2.14 Five pattern parts of the basic dress are called basic pattern block

Body measurements are employed in pattern making and the final garment measurement can vary depending upon the garment shape and the amount of ease added. Systems of pattern construction were devised in the early days of craft tailoring, long before the production of clothing was industrialised, as shown in Figure 2.13 (Miyoshi, 1985). They were designed to serve the needs of the busy tailor who required a guide for drafting garments directly on to the cloth. As each garment was cut individually to varying measurements, pattern drafting had to be simple and speedy in operation (Kunick, 1984). Figure 2.14 shows five pattern parts that make up a basic dress. They are called the basic pattern block, pattern foundation or sloper. This pattern set serves many purposes. It clarifies and helps the pattern maker understand the fit of a garment relative to the pattern shape. It is a record of the figure's dimensions. It is the foundation of the flat pattern making system and the basis of other secondary foundation patterns such as the torso, jacket, coat, pant, jump suit, swimwear, etc. Because the pattern is the basis for the flat pattern making system, the basic pattern must be perfected to eliminate all errors that would otherwise be passed on to each new design based on it. It is well worth the time and effort spent to analyse the fit of the garment and to make all corrections required to perfect the pattern.

2.3.3 Methods for Generating Pattern Blocks

There are three methods for generating patterns for apparel products used in the apparel industry. These three methods are commonly known as (1) flat pattern design, (2) drafting and (3) draping. Any of the three methods can produce a pattern for apparel that can be marked to distinguish seams, darts, tucks, pleats, yokes, pockets, and any other fit or design effect as they relate to the human form and to the design.

1. Flat pattern design is the development of designs from a basic block devoid of design details. Style details are produced by the manipulation of the pattern to produce the desired design. This is used in the moderate and low priced ready-to-wear garments. It is suitable for fabrics with some dimensional stability, a degree of body, and of medium weight. All blocks have no seam allowances.

2. Drafting is the drawing of a pattern on paper according to specifications, which may be taken from body or garment measurements. The measurement is transferred in a formulated or prescribed manner to paper, the lines and angles must intersect properly to produce a functional, well-fitting pattern. The patterns most appropriate to this development technique are those with a relatively simple shape and no design intricacies.

3. Draping is the development of a pattern by smoothing the fabric over the body, along the grain lines and suppressing the excess fabric into darts or dart equivalents. Draping is most used by couturiers (producers of high priced garments) and those who design lingerie. Draping is most useful (and almost necessary) with filmy, slippery, or gossamer fabrics. Most designers use some

combination of all three of these techniques in developing a pattern to transform a two dimensional fabric by means of shaping into a three-dimensional form (garment). The pattern is usually cut in fabric (muslin) and tried on the form or applied to the garment and then tried on toile. Testing the fit and styling by trying it on a form or a person is reverting to the draping technique.

The flat pattern method is most commonly used in the volume apparel industry. The design is developed in a two-dimensional form on paper, which is then used as a guide for cutting the fabric. Darts can be relocated or changed to equivalents such as seams, tucks, or pleats, but the pattern is always retained in its flat form. A flat pattern is economical in terms of fabric because the patterns are first developed on paper and can be engineered to improve fabric usage when fabric of various widths are used. The technique is faster than the draping method and far more economical of fabric.

2.3.4 Pattern Construction by Fitting a Garment

The assessment of the fit of the garment produced by the pattern maker and sample machinist is usually carried out by trying the garment on a body, often in the form of an employee in the clothing manufacturing company. Studies between garment stands used in the industry and actual human bodies reveal many differences in curvatures, proportioning, and especially in posture (Hudson, 1979). Some companies using the stands have established the practice of measuring them upon receipt to be sure they conform to the standard specified. Though it is possible to assess the fit and ease of the garment worn standing at attention by the use of these stands, it is not also possible to assess the comfort of the garment on the moving, physically active wearer. Fit considerations during activity are critical to the success. At this point it might be well to ask the question: what is a fitted pattern? A pattern-making instructor in Texas summed up the most succinct definition of fit in 1933. She defined fit as the presence of five standards or factors, and named them ease, grain, line, balance, and set. She defined any garment in which all of these standards were met as one that FITuj (Erwin, 1954). These five standards may be summarised and identified in the following way:

1. Ease refers to the looseness or tightness of the garment on the body. Adequate ease allows the wearer to move comfortably and gracefully and to perform tasks without unnecessary strain on the garment and without restraint imposed by the garment. Ease is the difference between the body's measurements and the garment's measurements. Not all garments require the same amounts of ease. The activity for which the garment was designed as well as the fabric's dimensional stability affects the standards of ease.

2. Line primarily refers to the seams of the garment. Vertical seams should appear to be perpendicular to the floor. Centre seams should occur on the centres of the body; side seams should appear to divide the body in half vertically. Shoulder seams, unless design effects indicate otherwise, should be equally visible from the front and back of the garment. Necklines should fit up closely against the neck, especially in the back, unless designed to occur lower. Sleeves should be set in and waistline seams should occur in line with actual body "points of articulation".

3. Grain refers to the fabric / pattern / wearer relationships. Garments should be cut from grain perfect material so that the grain line occurs parallel to or perpendicular to the floor when worn. Introduction of design effects and styling can change the grain relationships, but imperfect grain alignment of pattern and fabric at the cutting stage will result in mismatched plaids, or stripes which run skewed on the body neither parallel nor perpendicular to the wearer or the horizon. Less obvious but undesirable effects in solid colours can be detected in the way a garment tilts or hangs to one side. True bias occurs at a 45° angle to the selvages, not at angles of fewer or greater degrees.

4. Balance refers to the manner in which a garment extends from the body. Balance is probably most readily observed in a short sleeve, loosely fitted jacket, or a skirt. If the garment clings and / or reveals in one area and stands away from the body in another, balance does not exist. A balanced jacket should drop from the shoulders and extend from the right and left sides of the body and from the back and front to the same degree. This has to be assessed by individuals. It is impossible to predict asymmetry in the bodies of one's consumers.

5. Set is the final standard of fit. Erwin defined set as the absence of wrinkles. Wrinkles can occur in the three directions-vertically, horizontally, and diagonally. Vertical folds or wrinkles indicate that the garment is too large in circumference. Horizontal wrinkles indicate that the body is too large in an area below the wrinkles and so the garment moves up on the body to settle at a smaller circumference, which it fits. Diagonal wrinkles are the most telling.

They are really uncontrolled darts. They usually indicate that the fitting dart is releasing an insufficient amount of fabric at its point to accommodate body bulge. To control diagonal wrinkles, darts are usually increased in size. The principle of apparel fit involves the use of darts or dart equivalents (seams, pleats, tucks, gathers, and eased seams) to provide fullness for bulges.

Analysing a pattern will reveal that shaped seams, darts, and their equivalents (in the form of ease or pleats or other fullness) require extra fabric to cover the bulges which are commonly found at the shoulder apex, shoulder blade, bust or chest, elbow, side hip, back hip, abdomen and knee.

2.4 Fabric and Garment Evaluation

2.4.1 Fabric Evaluation

The mechanical properties of cloth, which is used by clothing manufacturers, is of great importance where the consistency of quality and performance of the fabric is required. Two main papers appear direct on fabric tensile testing. In the first of these, Aonuma and Murakami (1974) began a series of studies on an electro-hydraulically controlled load-input tester for testing the mechanical properties of textile fabrics, the initial work being a trial production of the load-input tensile-testing machine. The second paper is a major attempt to rectify the dearth of information. In it Mahar, Dhingra, and Postle (1987) reported the results of an extensive study involving the variability of measuring low-stress fabric mechanical and surface properties for a range of 30 wool and wool-blend suiting fabrics. They used seven sets of KES-F instruments for inter-laboratory tests in Australia, Japan, Germany, the U.K., New Zealand, and the

People's Republic of China. The authors gave values for the repeatability and reproducibility of 37 parameters and ratios characterising the elastic and inelastic components of fabric deformation in tension, shear, bending and lateral compression, as well as fabric surface behaviour, that is, surface topography and friction. They also specified measurement precision in terms of the maximum error for these parameters and quote the variance of each measurement in terms of its within-laboratory, between-laboratories, and specimen / laboratory-interaction components. Recommendations were made for both the in-house product and process-development situations (with a laboratory) and for specifications for commercial transactions (between laboratories) as to the number of tests that should be performed in order to achieve a given level of precision. They suggested that, though varying numbers of tests are recommended for some parameters, a general rule of three tests per sample might be taken as a guide.

2.4.2 Garment Evaluation

Current surveys of garment wearer trials have found the results helpful for the evaluation of woven stretch garments. Subramaniam (1985) carried out a literature survey of fibre failure and fatigue, with particular reference to some methods of testing. Hattori and Niwa (1981) examined fatigue phenomena of woven fabrics caused by the effects of wearing. In their work, they investigated the change in mechanical properties of such fabrics during wearing, with a view to developing a method of test to predict fatigue phenomena. They carried out a wearing test of three types of men's worsted slacks, of different construction, for about 100 hours during three seasons. They calculated the mechanical properties of specimens taken from various portions of the garments and used the KES-FB apparatus to determine the handle values. In addition, they observed fibre, yarn, and fabric-surface morphology after fatigue by using stereomicroscopy and scanning electron microscopy. They noted a loss in tensile and compressive recovery, together with a threefold increase in hysteresis during bending or shearing, through the latter effect depends on fabric construction. As expected, Hattori and Niwa found that the extent of change is affected by the location of the body site, from which the specimen is taken, and wool-scale damage is evident, as also is a strength loss in all the fibre assembles involved. Research into the durability of specific fibres also appears. Hawkins and Thomas (1982), in a presentation at a symposium dealing with chemical treatments on textiles, evaluated the wear-life performance of men's all-cotton dress shirts finished by four different application methods. Members of the Texas Tech University (1984) illustrated graphically, in the final part of a report on the effects of cotton ageing, the influence of age on selected fibre and yarn properties. The results show that, whereas there is a decline in cotton-fibre strength with age, which may result in weaker yarns, no drastic loss in yarn strength should be experienced. Hojo (1986) discusses the de-scaled wool known as Vantean in relation to its physical and chemical properties and wearing performance and provided 24 references to earlier publications. Kokoshinskaya and Krylova (1989) compare the properties of fabrics woven from ring-spun and rotor-spun wool yarns and find that the wear-resistance of the fabric from the rotor-spun yarns was better than that from the ring-spun yarns, whereas there is no deterioration in the aesthetic properties or drape.

Dowlen (1975) performed an evaluation of experimental cotton / acrylic-fibre tricot jersey fabrics. He reported the results from a laboratory determination of selected physical and aesthetic properties of four experimental blended-fibre apparel fabrics after using standard and non-standard test procedures to evaluate performance. He felt that the drape of the materials was good but that stiffness was difficult to evaluate because of curling. He judged the greige fabric to be better than the finished one and postulated that properties such as snagging may be influenced by the finishing process. Dowlen also found that pilling-resistance in the fabrics was poor but was improved by increased cotton content and that smoothness or air-permeability could be predicted easily. He commented on bursting strength and dimensional change in relation to fabric construction, with an interpretation of the results of a radial test force used in his programme, and recommended the production of garments from each of the blends for further study during extended service.

Koblyakov and Rusiya (1986), evaluating the quality of knitted fabrics for tracksuits with the aid of reliability criteria, examined statistically the results of a number of wear-trial tests on tracksuits from knitted acrylic-fibre / nylon 6 / wool fabrics, defects and abrasion-resistance and predict that the probability of the tracksuits remaining in an acceptable condition for between 18 months and two years without failing has between 0.72 and 0.51. Wada and Takatera (1984) discussed physical properties and wear tests of water-absorbent polyester fibres, and Zhu et al. (1987) studied the relationship between the fatigue properties of PPTA [Poly (phenylene terephthalamide)] fibre and the different spinning processes. They investigate various fabrics for improving the special attention paid to dry-spinneret wet spinning. Hillermeier (1985) outlined the characteristics of aramid and carbon fibres and their past development and compared the major properties of Twaron HM aramid fibres and those of Tenax carbon-fibre continuous-filament yarns. He detailed new methods of testing the properties of aramid fibres and differences between aramid and carbon-fibres and paid particular attention to modulus, moisture absorption, ballistic properties, and end-uses. The author has found useful ideas in previous methods on evaluating the qualities of woven stretch garment here. The assessment contains two parts, one being an evaluation on the changes of pattern construction of a garment and the other one being an evaluation of wear durability (for physical qualities aesthetics).

(1) Manual measurement: This is a method to capture the body size by using tape measurements on a human body. An accurate body size is used to draft the pattern construction and correct the garment form.

(2) 3D body Scan System: This is current equipment used on body size measurement and garment evaluations. It is a kind of automatic and scientific method. In theory, body scanning can eliminate the need to take the battery of hand measurements now required for making customised apparel. The technology not only makes the process faster but more accurate, and in time will become more affordable. (Rusell, 2000, Nottingham Trent University, 1999, University of Dresden, 1999, Yu, 1999, Yuen, 2000, Kang and Kim, 2000, McCartney and Hinds, 2000, Dai (et al), 2000)

(3) Video or camera capture and image analysis: Camera captures and image analysis are using two dimensional assessment procedures of essentially two-dimensional objectives. Video method is the analysis of images of a garment, which are video captured from taped segments of a fit trial. In related textile fields, computerised methods of analysing video-captured images have been used as an objective measure of various properties (Kohn and Ashdown, 1998).

A new approach to the effective use of woven stretch fabrics without uneconomical try and error system is obviously needed. The development of a scientific and simplified system applicable to all woven stretch fabrics and two-dimensional garment patterns for body contouring apparel forms led to the following Chapters.

3

MATERIAL AND EQUIPMENT

CHAPTER 3

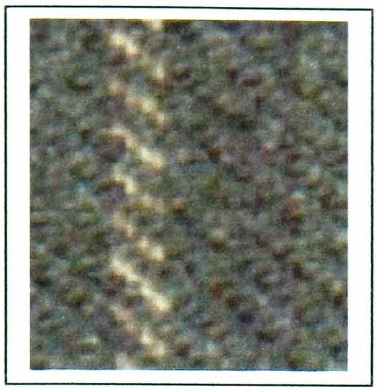
MATERIALS AND EQUIPMENT

3.1 Introduction

The woven structures and component of fabrics influence the extension and recovery properties of woven fabric. Thirteen woven stretch fabrics with different woven structures and fibre components were selected. A non-stretchable woven fabric was also used as a control sample. This chapter discusses the materials and equipment including the Instron Tensile Tester and the Tri Form ™ 3D Scanner used in this project.

3.2 Woven Stretch Fabrics

Thirteen woven stretch fabrics (A to M) and a normal woven suiting fabric (S) supplied by NEXT UK Ltd. and Taiwan Textile Federation were used. The fabric samples and their weave structures are discussed below. The pattern repeat for the fabric is shown in highlighted box, where the 'x' and 'o' are weft and warp yarns appeared on surface.



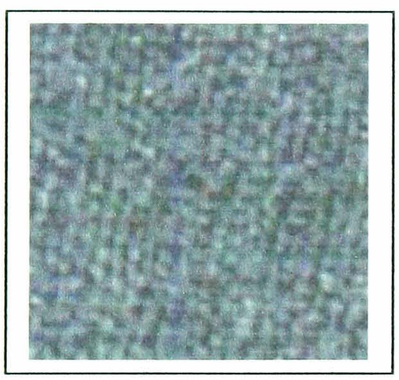
	x	o	o	x	x	o	o	x
	x	x	o	o	x	x	o	o
	o	x	x	o	o	x	x	o
	o	o	x	x	o	o	x	x
4	x	o	o	x	x	o	o	x
3	x	x	o	o	x	x	o	o
2	o	x	x	o	o	x	x	o
1	o	o	x	x	o	o	x	x
	1	2	3	4				

Magnified view of fabric **sample A** and its weave structure

Warp (Brown / Yellow) and weft yarns:

- Wool / polyester staple fibre blend
- Single ply, core spun with elastane mono-filament

Two way stretch fabric



	o	x	x	o	x	x	o	x
	x	o	x	x	o	x	x	o
	x	x	o	x	x	o	x	x
	o	x	x	o	x	x	o	x
	x	o	x	x	o	x	x	o
3	x	x	o	x	x	o	x	x
2	o	x	x	o	x	x	o	x
1	x	o	x	x	o	x	x	o
	1	2	3					

Magnified view of fabric **sample B** and its weave structure

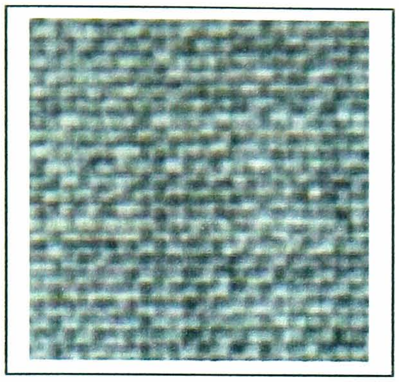
Warp yarns:

- single ply worsted yarn of wool

Weft yarns:

- single ply worsted and core spun with elastane mono-filament

Weft stretch fabric



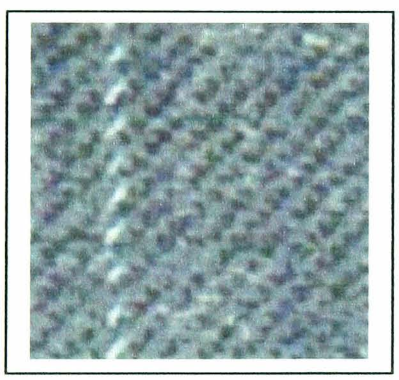
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample C** and its weave structure

Warp and weft yarns:

- wool / polyester staple fibre blend
- single ply, core spun with elastane filament

Two way stretch fabric



	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample D** and its weave structure

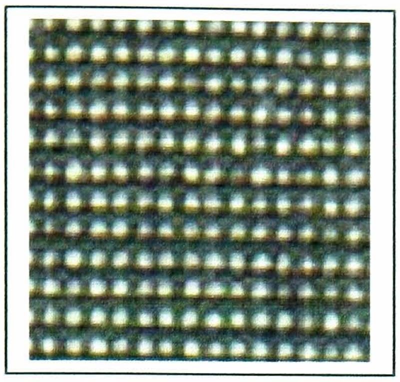
Warp and weft yarns:

Blue warp and weft yarns - wool / polyester staple fibre blend

Grey warp yarn - polyester filament fibre

Single ply, core spun with elastane mono-filament

Two way stretch fabric



	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample E** and its weave structure

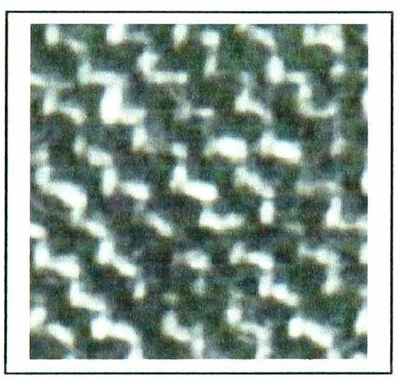
Warp (cream / black) yarns:

- wool / viscose staple fibre blend
- polyester filament fibres } Double ply yarns

Weft yarns:

- double ply, core spun with elastane filament

Weft stretch fabric



	x	o	o	x	x	o	o	x
	x	x	o	o	x	x	o	o
	o	x	x	o	o	x	x	o
	o	o	x	x	o	o	x	x
4	x	o	o	x	x	o	o	x
3	x	x	o	o	x	x	o	o
2	o	x	x	o	o	x	x	o
1	o	o	x	x	o	o	x	x
	1	2	3	4				

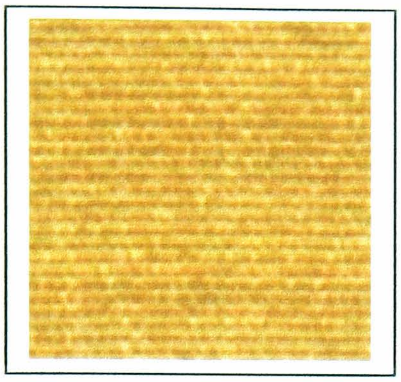
Magnified view of fabric **sample F** and its weave structure

Warp and weft yarns:

White yarn - polyester filament fibre
- elastane mono-filament } Double ply yarns

Black yarn - wool/viscose staple fibre blend
-single ply, twisted with elastane mono-filament

Two way stretch fabric



	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample G** and its weave structure

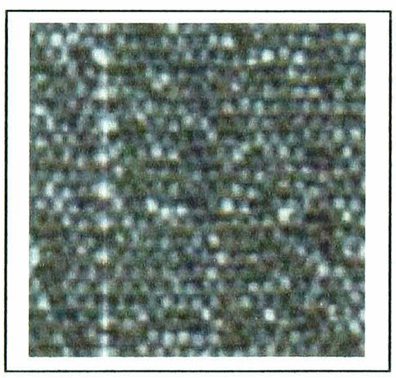
Warp yarn:

- textured yarn of nylon filament fibres

Weft yarn:

- interlaced yarn of nylon filament fibres with elastane mono-filament

Weft stretch fabric



	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample H** and its weave structure

Warp (white and black) yarns:

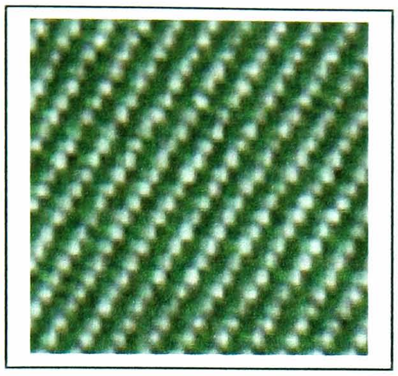
- single ply yarn of nylon filament fibres

Weft yarns:

-nylon filament fibres

- two ply yarn (1 ply: White & 1 ply: Black) twisted with elastane mono-filament

Weft stretch fabric



	x	x	o	x	x	o	x	x
	x	o	x	x	x	o	x	x
	o	x	x	x	o	x	x	x
	x	x	x	o	x	x	x	o
4	x	x	o	x	x	x	o	x
3	x	o	x	x	x	o	x	x
2	o	x	x	x	o	x	x	x
1	x	x	x	o	x	x	x	o
	1	2	3	4				

Magnified view of fabric **sample I** and its weave structure

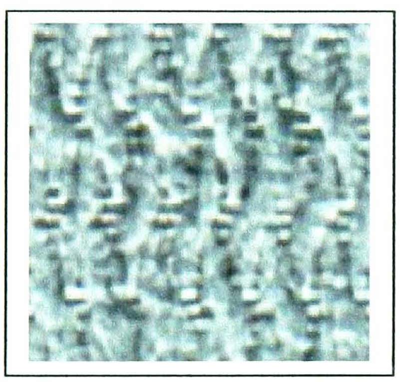
Warp (green) yarns:

- textured yarn of polyester filament fibre

Weft (white) yarns:

- cotton fibre
- single ply, core spun with elastane mono-filament

Weft stretch fabric



x	x	o	x	x	x	x	x
o	o	x	x	x	x	x	x
o	x	o	x	x	x	x	o
x	o	x	x	x	x	o	x
x	o	o	x	x	o	x	o
x	x	o	x	o	x	o	x
x	x	x	o	x	o	x	o
x	x	x	x	o	o	x	o

Magnified view of fabric **sample J** and its weave structure

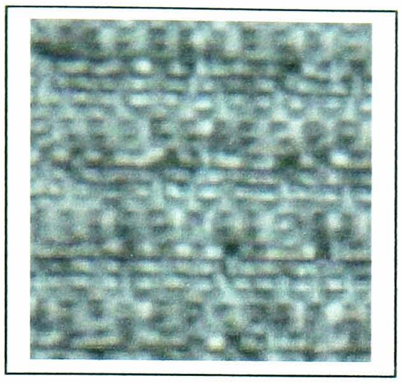
Warp yarns:

- textured yarn of polyester filament fibre

Weft yarns:

- polyester filament fibre
- single ply, twisted with elastane mono-filament

Weft stretch fabric



	o	x	o	x	x	x	o	x
	x	o	x	o	x	o	x	o
6	o	o	o	x	o	x	o	o
5	o	o	x	o	x	o	o	o
4	o	x	o	x	o	x	o	x
3	x	o	x	x	x	o	x	o
2	o	x	o	x	x	x	o	x
1	x	o	x	o	x	o	x	o
	1	2	3	4	5	6		

Magnified view of fabric **sample K** and its weave structure

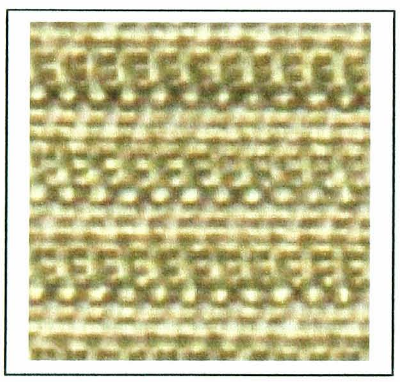
Warp yarns:

- textured yarn of polyester filament fibre

Weft yarns:

- polyester filament fibre
- single ply, twisted with elastane mono-filament

Weft stretch fabric



	x	o	x	o	x	o	x	o
	o	o	o	x	o	x	o	o
6	o	o	x	o	x	o	o	o
5	o	x	o	x	o	x	o	x
4	x	o	x	x	x	o	x	o
3	o	x	o	x	x	x	o	x
2	x	o	x	o	x	o	x	o
1	o	o	o	x	o	x	o	o
	1	2	3	4	5	6		

Magnified view of fabric **sample L** and its weave structure

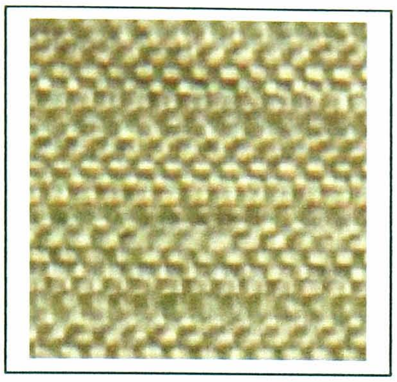
Warp yarn:

- textured yarn of polyester filament fibre

Weft yarn:

- cotton fibre
- single ply, core spun with elastane mono-filament

Weft stretch fabric



	x	o	o	o	x	x	x	o
	o	o	x	x	o	x	o	o
6	x	o	x	x	o	o	x	o
5	x	x	o	o	o	x	x	x
4	o	x	x	o	x	o	o	x
3	o	x	o	x	x	o	o	x
2	x	o	o	o	x	x	x	o
1	o	o	x	x	o	x	o	o
	1	2	3	4	5	6		

Magnified view of fabric **sample M** and its weave structure

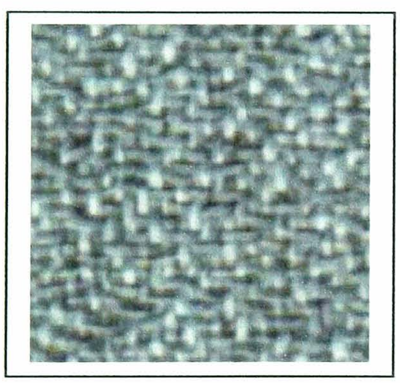
Warp yarns:

- textured yarn of polyester filament fibres

Weft yarns:

- cotton fibre
- single ply, core spun with elastane mono-filament

Weft stretch fabric



	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
	x	o	x	o	x	o	x	o
	o	x	o	x	o	x	o	x
2	x	o	x	o	x	o	x	o
1	o	x	o	x	o	x	o	x
	1	2						

Magnified view of fabric **sample S** and its weave structure

Warp and weft yarns:

- polyester filament and viscose stable fibre
- single ply yarn of polyester/wool/viscose blend

Non stretch fabric

The weave structure of the fabrics and their fabric weights were determined. The composition of these fabrics and their structural characteristics are given in Table 3.1.

Table 3.1: Some characteristics of the fabric samples

Fabric Sample	Composition	Yarns		Weave	Ends per inch	Picks per inch	Twist Level (turns / inch)		Weight (g/m^2)
		Warp	Weft				Warp	Weft	
A	Wool 60% Polyester 36% Elastane 4%	Z, twist with elastane	Z, twist with elastane	2/2, 45° twill	75	85	30	30	285
B	Wool 97% Elastane 3%	S, twist No elastane	S, twist with elastane	1/2, 70° twill	70	60	15	15	230
C	Wool 60% Polyester 36% Elastane 4%	S, twist with elastane	S, twist with elastane	Plain	60	60	25	25	190
D	Wool 60% Polyester 36% Elastane 4%	S, twist with elastane	S, twist with elastane	1/2, 45° twill	66	64	25	25	225
E	Polyester 66% Viscose 33% Elastane 1%	S, double twist No elastane	S, double twist with elastane	Plain	75	60	25	25	190
F	Wool 53% Viscose 27% Polyester 18% Elastane 2%	Black: S, twist White: Z, double twist with elastane	Black: S, twist White: Z, double twist with elastane	2/2, 45° twill	50	50	10	10	335
G	Nylon 92% Elastane 8%	Textured yarn No elastane	interlaced yarn with elastane	Plain	275	66	textured	interlaced	80
H	Polyester 98% Elastane 2%	Z, twist No elastane	Z, twist with elastane	Plain	105	50	20	15	190
I	Polyester 48% Cotton 50% Elastane 2%	Textured yarn No elastane	Z, twist with elastane	3/1, 60° twill	82	54	textured	15	255
J	Polyester 94% Elastane 6%	Textured yarn No elastane	Low-twisted with elastane	Diagonal twill	127	48	textured	low (degree)	205
K	Polyester 94% Elastane 6%	Textured yarn No Elastane	Low-twisted with elastane	Rib	127	48	textured	low (degree)	205
L	Polyester 35.4% Cotton 60% Elastane 4%	Textured yarn No elastane	Z, twist with elastane	Rib	127	48	textured	15	180
M	Polyester 35.4% Cotton 60% Elastane 4%	Textured yarn No elastane	Z, twist with elastane	Twill	127	48	textured	15	180
Control Fabric S	Wool 38% Polyester 50% Viscose 12%	Z, twist No elastane	S, twist No elastane	Plain	60	60	15	25	210

3.3 Instron Tensile Tester

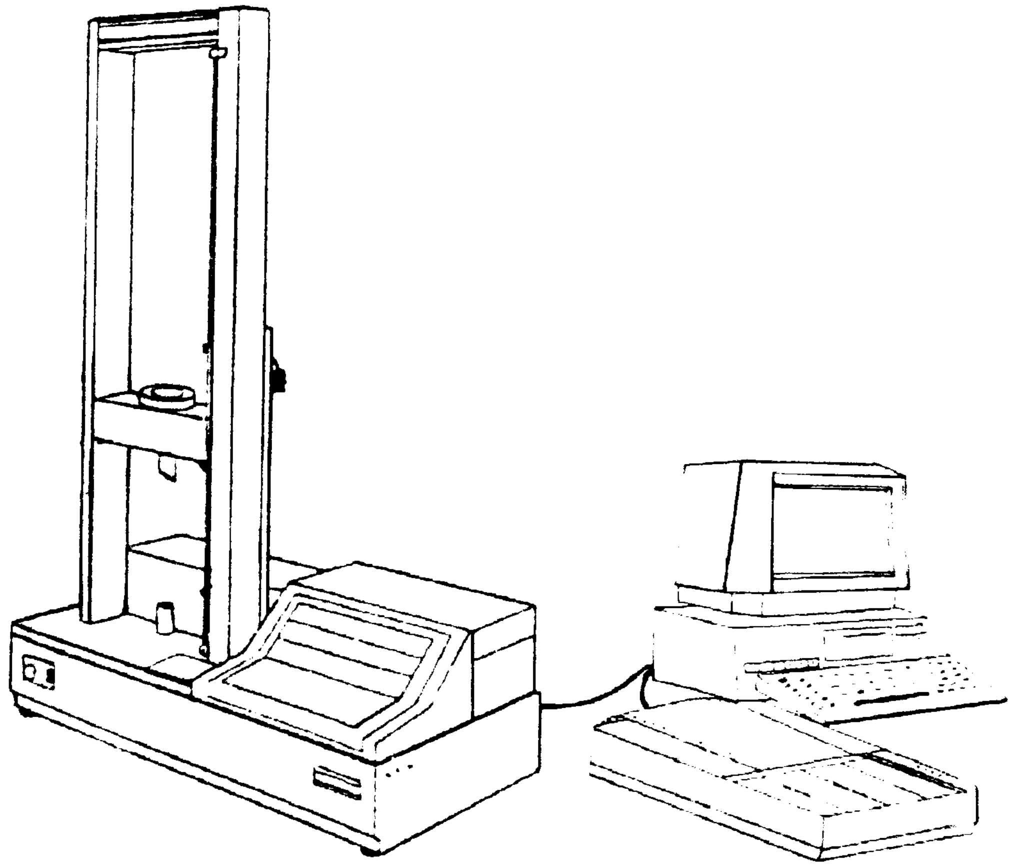


FIG. 3.1 Diagram of Tensile tester and PC based Series IX System

Fabric tensile properties including extension and recovery were determined using an Instron 4302 tensile tester as illustrated in Figure 3.1. The Instron 4302 was linked to a computer and printer, and used Series IX software. The programme included machine control, test criteria, crosshead stop criteria and data sampling. The machine could control the action of the crosshead to stop at a predetermined limit either on load or extension, so stretching the fabric to different predetermined extensions or load. Other parameters such as crosshead speed and specimen dimensions were able to be set up for the experiments. The displacement (or strain) and load (or stress) was measured from the start of the test.

3.4 Tri Form ™ 3D Scanner

3.4.1 Introduction

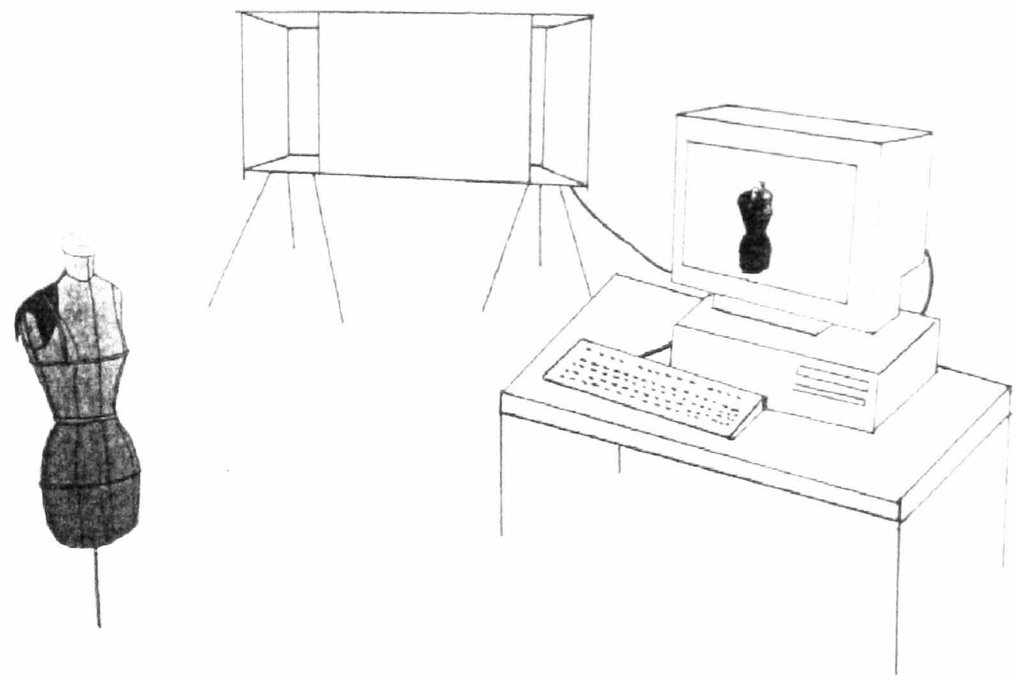


FIG. 3.2 Diagram of Tri Form ™ 3D Scanner and PC based 3D image capturing System

As illustrated in Figure 3.2, the Tri form® TorsoScan system is an integral torso scanner designed for garment design, fitting and fabric & pattern assessment. The image capturing and processing technique digitises the surface of the upper body and converts it to a point-cloud containing up to 1Million three dimensional co-ordinates and associated colour data. This can be used in a variety of third party software applications for display or analysis. Capturing the accurate shape of the torso digitally is a new technique, which can assist in the assessment of fabric and pattern changes in this project.

3.4.2 Image Capturing and Measuring

The Tri Form ™ system is supplied with basic software, which comprises three modules: TriCapture, TriEdit and TriAnalyse. They can perform the basic capturing, viewing, editing and stitching. TriCapture, TriEdit and TriAnalyse were used for analysing the performance of the garments in this project.

- TriCapture: This module provides set up, calibration and operation facilities of 3D capture units. The output from the module was a single point cloud in TFM format.
- TriEdit: This is a comprehensive editor which inputs TFM files and which can perform a range of different editing functions on a file, or combine several files (stitching) as well as being able to store the files in a number of different output formats.
- TriAnalyse: An analysis tool for 3D surfaces, which can analyse a TFM 3D image and provide measurements of different aspects of the object.

4

DETERMINATION OF FABRIC STRETCH AND RECOVERY PROPERTIES OF WOVEN STRETCH FABRICS

CHAPTER 4

DETERMINATION OF FABRIC STRETCH AND RECOVERY PROPERTIES OF WOVEN STRETCH FABRICS

4.1 Introduction

Fabric stretch and recovery properties are caused by and dependent on the combined characteristics of fabric structure and yarn and fibre properties. These properties can affect the value and level of fabric extension and recovery of a garment during wear. The stretch and recovery properties in a fabric can be achieved by several different methods. It is mainly dependent on the end uses of the fabric and desired stretch level.

There are three important properties, which have to be considered primarily in the construction of any fabric. These are stretchability, recovery and freedom of movement. These properties are designed to give good stretch and recovery properties.

(1). Stretchability:

It is obvious that no fabric can be regarded as a stretch fabric unless its structure can deform significantly when subjected to relatively small forces (all fabrics will stretch to some extent if large enough forces are applied). Woven stretch fabrics are able to be stretched easily at lower forces.

(2). Recovery:

It is also necessary to engineer recovery properties into the structure to allow the fabric to return rapidly to its relaxed condition no matter how often or how much (within reasonable limits) it is stretched. This is achieved by providing internal recovery forces within the fabric structure. The yarns from which the fabrics are made up provide such forces. These may be twisting and bending forces within the fibres (such as in false-twist stretch yarns), elastic tension forces (such as in fabrics containing rubber or synthetic elastomers), or bending and unbending forces alone (such as in certain types of woven stretch fabric or ordinary knitted structures).

(3). Freedom of movement:

Finally, to ensure minimum permanent extension or residual extension and rapid recovery from stretch, and in order that the fibres and yarns can return to their relaxed original form, it is necessary that they have sufficient freedom of movement within the structure. Therefore, the stretch potential must be adequate and the recovery forces resisting stretch must usually be relatively small. These same recovery forces must be great enough to overcome internal fabric resistance and return the fabric to its original dimensions within a short time due to the forces' release of extension.

Furthermore, woven stretch fabric is one of the fabrics designed to give good stretch and recovery properties and provide certain advantages. It not only keeps the appearance of woven fabric but also contains the stretch properties of stretchable fabric e.g. knitted fabric. The main advantages of stretch are:

(1). Providing greater comfort for the wearer.

(2). Producing a slimmer fitting where required.

(3). Preventing permanent stretching of strained areas.

(4). Lengthening the garment's life by reduced strain.

(5). Assisting the flexibility of sizing.

Moreover the stretch of woven stretch fabric is not the whole story. The important point is the recovery (elastic recovery) factor, which is more difficult to measure or assess. The residual extension, otherwise known as permanent extension, is the relative status of the woven stretch fabric. The dictionary definition of *Elastic* is "Having the quality of returning to that form or volume from which it has been compressed, expanded or distorted" i.e. its power to return.

Therefore, to be able to accurately measure or assess the stretch and recovery properties of woven stretch fabrics it is necessary to use an objective tensile test method. To establish the suitable test methods and instruments two tasks are involved. The first is the survey and discussion of current tensile test methods and the second is the terms of definition and calculation used in the tests and the results.

Current Tensile Test Methods

Any stretchable fabric will exhibit stretch (extension) behaviour under a certain tension (load) and recovery properties that can be quantified by a load-extension curve on a tensile tester. These results are useful in correlating the stretchability and elasticity of a fabric. The instrument used in the test can be a constant rate of load (CRL) type, a constant rate of extension (CRE) type or a constant rate of traverse (CRT) type. Samples have to be conditioned in a controlled environment of 20 ° ± 2 °C and 65% ± 2% R.H, as defined in British Standard BS 1051. Samples should be conditioned for at least 24 hours. Specimens taken from the full width fabric should be at least one-tenth of the width of the fabric from the selvage (ASTM D1776). Before discussing further it will be necessary to define some of the terms commonly used in fabric extension, residual extension and recovery. There are illustrated in Figure 4.1 (Denton, 1980). In Figure 4.1 shows **(A)** the unextended fabric, **(B)** the extended fabric; the extension depends on the properties of the fabric and the stretching force applied to it. **(C)** shows the fabric after stretching; the fabric may not return to its initial dimension, at least not immediately. The extension, residual extension and recovery usually expressed as a percentage of the unextended fabric length.

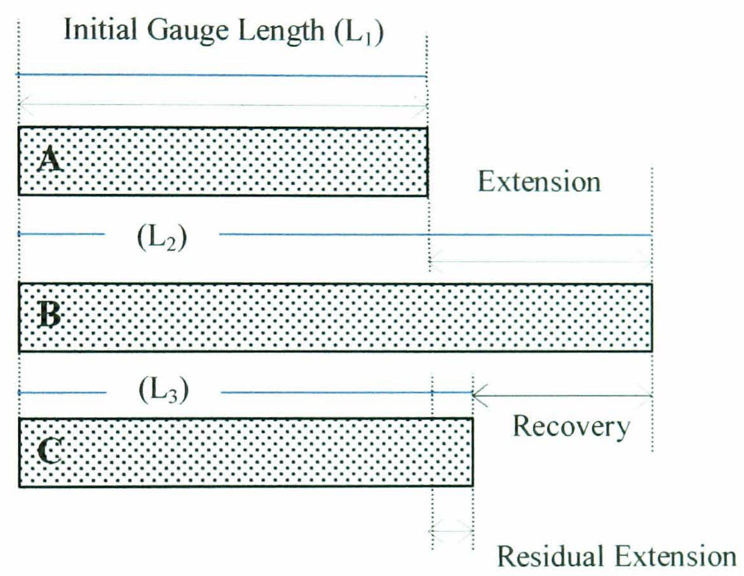


FIG. 4.1 The terms of definition used in the study

The tensile testing has two important objectives: (a) quality control and (b) prediction of the fabric performance during the tailoring and wearing. The important properties of woven stretch fabric to quality control are (1) fabric stretch under load, (2) prompt recovery from stretching, (3) the way of stretching and (4) permanent extension or residual extension. Hence using of suitable tensile test method and instruments to predict fabric performance is important and necessary.

There are four different ways to test tensile properties such as CRE type, CRT type, CRL type and multiple purpose type which can be provided by the current testing instruments.

(1). CRE Type:

This is a testing method in which the rate of increase of specimen length is uniform with time. In some testing instruments based on the CRE, the top jaw is not fixed but needs a certain amount of movement in order to operate the load-indicating mechanism. This movement relative to the bottom jaw prevents the extension of the specimen at an absolutely constant rate.

(2). CRT Type:

A testing method in which the pulling clamp moves at a uniform rate and the load is applied through the other clamp. The pulling clamp moves appreciably to actuate a load - measuring mechanism, so that the rate of increase of load or elongation is usually not constant and is dependent on the extension characteristics of the specimen. Nevertheless, the bottom jaw traverses downwards at a constant rate and therefore the machines are referred to as constant rate of traverse tester or CRT machines.

(3). CRL Type:

A testing method in which the rate of increase of the load is uniform with time after the first 3 seconds and the specimen is free to elongate, this elongation being dependent upon the extension characteristics of the specimen at any applied load value.

(4). Multiple Purpose Type:

Suitable test methods had to be developed for elastic fabrics. Warp and filling stretch testing comprises total stretch and elastic stretch testing to yield elastic stretch. The so-called elastic recovery (residual elongation) or the degree of elastic stretch reveals the capability of the elastic fabric to regain its original shape after use deformation. All stretch tests require specimen conditioning (Rubel, 1983).

Presently different countries may have their own different and variable national test methods and standards. Most major manufacturers use their own test methods and quality guidelines, such as Du Pont Ltd. (Du Pont, 1981). Many high street fashion retail store chains, for example, Marks & Spencer and British Home Stores, use their own test methods to guarantee this quality; while for fashion designers and consumers, there are five currently popular methods used so-called 'measurement or evaluation' methods as described below:

(a). Method 1:

This is the Hand Extension Test. This is based on the stretching a fabric strip of a known original length by hand. The stretched length is then measured expressed as percentage of original length. Because many retailers or small-medium enterprises are not equipped with a laboratory, they frequently judge woven stretch fabric manually. This method is widely used by fashion designers and consumers. It can also be seen in many commercial trading activities. The hand tensile test method provides an initial rough idea of fabric extension and offers an initial guide to designers, pattern making / cutting and technicians.

(b). Method 2:

The second method is a CRL Tester or Hanger / Load Apparatus e.g. Fryma extension / recovery test method. The Fryma test method is carried out by following British Standard BS 4294:1968 (or ASTM D3107, 1975) and operated on the Fryma extensionmeter and other testers. The test principle is stretching a specimen of standard dimensions e.g. around 200 X 75 mm (or around 500 X 5 mm) for woven stretch fabrics 75 X 75 mm for knitted fabrics by applying a specified load e.g. 3 kg or 6 kg (or cycling three times from 0 to 4 lb. load) which is increased gradually for 10 ± 2 sec. then reduced within 7.5 ± 2.5 sec. The extension is measured and the tension removed. The length of the unstressed specimen is measured after recovery.

(c). Method 3:

The third method uses a Multi-functional Tensile Test Instrument (which can provide even CRL, CRE or CRT), such as KES-FB1, Hounsfield or Instron Tensile Tester, etc. The test principle is based on stretch measurement at a given specified force (load) or percentage extension at a constant rate condition. This method comes from British Standard BS 4952:1992 'Method of test for Elastic Fabric' or ASTM D1775 'Testing Elastic Fabrics'.

(d). Method 4:

This uses a Constant Rate of Extension Electronic Dynamometer. A loop of specimen of e.g. around 200 X 75 mm is cycled five times at a constant rate of extension on a tensile tester between zero and 150 N load.

(e). Method 5:

This uses a Biaxial Tensile Tester. The instrument is designed mainly to measure continuous biaxial stretches in the process of uniaxial deformation of fabrics, while the transverse deformation is forced to zero. For example, in Kawabata KES-G2 strip biaxial tensile tester, the tensile rate can either be 60 or 120 mm/min and allow only one sample size of 140 X 165 mm (effective specimen dimensions are 100 X 100 mm) at the instrument geometry. However there are several sources of error shown in the use of such kinds of biaxial tensile testers. For example, stresses in the regions near and between the clamp segment are lower than elsewhere, and the regions between the clamp rows and the specimen edges may be only stressed uniaxially.

Among the different test methods discussed above, although the Fryma extensionmeter is operated manually, it is still widely used in textile and clothing industry because it is easy to use and is less expensive than most other methods. Furthermore test methods on instruments, which employ a constant rate of traverse tensile test, are largely automated and commonly used for experimental test (e.g. the Instron tensile tester or Hounsfield tester), and they can reduce experimental errors. For a more accurate assessment this method can be used, and all are based on holding the specimen for a specific time at a fixed load. In these kinds of test methods it appears that there is a big difference between the specified load and the specified extension used in stretch tests for stretchable fabrics. It is better to predict the degree of fabric extension and recovery under a fixed extension rate tensile test method especially for woven stretch fabric.

In this study it was decided to use the Instron Tensile Tester to calculate the amounts of fabric extension, residual extension and recovery of thirteen selected woven stretch fabrics. Although the Fryma extensionmeter (manual method) is extensively used in the textile industries e.g. Toray (fabric manufacturing and finishing), Ashmore Textile (finishing), Marks & Spencer, NEXT Ltd., etc. the Instron Tensile Tester offers the more consistent results. And BSI recommended that BS 4952:1992 'methods of test for elastic fabric' should be used and this superseded BS 4952:1973 and BS 4294:1968 which were withdrawn.

Furthermore a load / extension test method was introduced by Du Pont Ltd. (Du Pont, 1976) and used in predicting fabric stretch and recovery properties of woven fabrics containing elastane. The test method uses a four pound load which is equalled to 17.79 Newton (ASTM D3107, 1975). In this research work, an 18 Newton was used and is within the recommendations given in British Standard BS 4952:1992. Accordingly the thirteen fabrics used in this work were all woven fabrics containing elastane. Hence the fabric stretch and recovery properties at this fixed load were determined and evaluated.

Lindberg found that the most important direction for stretch is in the bias (Disher, 1980; Lindberg, 1966). The direction of stretch in garments has a significant effect on comfort, fit and performance. Horizontal stretch gives the preferred balance of comfort, fit and performance in most garments and improves bias stretch with the exception of tensioned slacks. Therefore the major aim in this work was to analyse and discuss the results of the thirteen fabrics in the weft and 45°-bias fabric directions. Du

Pont (1976) suggested that a woven stretch garment should meet the recommendation that tailored clothing should have an average residual extension not exceeding 3.0%. Therefore a recommended maximum residual extension is set at this level, and assumes that the appearance of a woven stretch garment is not affected if this level is not exceeded during wearing.

Two tensile test methods were used to compare fabric extension, residual extension and recovery at the same condition to see whether the methods could determine the fabric stretch and recovery properties. The first method was a fixed load tensile test developed by following Du Pont's load / extension test method. The second method was a fixed extension rate for tensile test, which is referred to the constant rate of traverse tensile test method, and the standard expressed in Method-3. Three samples from each warp, weft and 45°-bias directions of the thirteen woven stretch fabrics were tested and the results are presented in Chapter 4.

4.2 Objective

The objective of this chapter is (1) to determine fabric stretch and recovery properties, (2) to predict the degree of fabric extension and recovery, and (3) to determine the acceptable extension level of each fabric individually for using in pattern reduction and alteration of woven stretch garment. The fabric stretch and recovery properties of thirteen samples can be evaluated by applying the objective tensile test methods on fabric specimens. These properties are related to garment pattern design and alteration in later chapters.

4.3 Test Method

4.3.1 Machine Parameters and Test Conditions

Testing machine:	Instron 4302
Specimen dimensions:	260 mm x 70 mm
Number of tests:	3 repeats for each sample for each direction (warp, weft or 45°- bias directions)

Test conditions:

Gauge length:	200 mm
Maximum capacity of load cell:	1 KN
Crosshead speed:	200 mm/min
Conditioning:	20 ± 2 °C and 65 ± 5% R.H.

4.3.2 Preparation of Specimens

Thirteen woven stretch fabrics (A to M) as described in chapter 3 were prepared for test.

(1) Conditioning fabrics at 20 ± 2 °C and 65 ± 5% R.H. for not less than 2 days prior to cutting into the test specimens.

(2) Cutting three test specimens, of 260mm by 70 mm each, with the longer length parallel to the warp, weft and 45°- bias fabric grain directions.

(3) Reduce the specimens to 50 mm in width by removing approximately the same number of yarns from each side of the specimen.

(4) Place benchmarks 200 mm apart in the centre part of each specimen using a marking pen (30mm from each end of specimen for clamping).

4.3.3 Determination of Extension and Recovery Properties of Woven Stretch Fabrics at a Fixed Load

A fabric specimen (200 mm X 50 mm) was carefully clamped on the Instron 4302 Tensile Tester. The fabric specimens with 200mm gauge length were stretched at a speed of 200 mm/min until they reached a load force of 18N and then returned to their original gauge length. This was repeated five times. The value of the maximum extension was recorded by the computer. Then the residual extension of the specimens after five repeats were determined by stretching the slack of the fabric sample again at sixth time just before the stress of fabric specimen started to arise again and by measuring the length of extension at that time. Figure 4.2 is the sample for the load-extension curves of the fabric, which was repeatedly stretched five times. It was found that at the fifth repeat the extension was almost the same as the fourth repeat. There was almost no further extension taking place. Therefore the extension, recovery and residual extension were evaluated after five repeat stretches. Prior to stretching, the fabric specimen had an initial gauge length between the clamps of the Instron. The fabric was stretched to some extent until reaching a certain tension load, which was applied. After the load force is removed the fabric may not return to its original dimension, at least immediately as shown in Figure 4.3. The extension, recovery and residual extension were calculated.

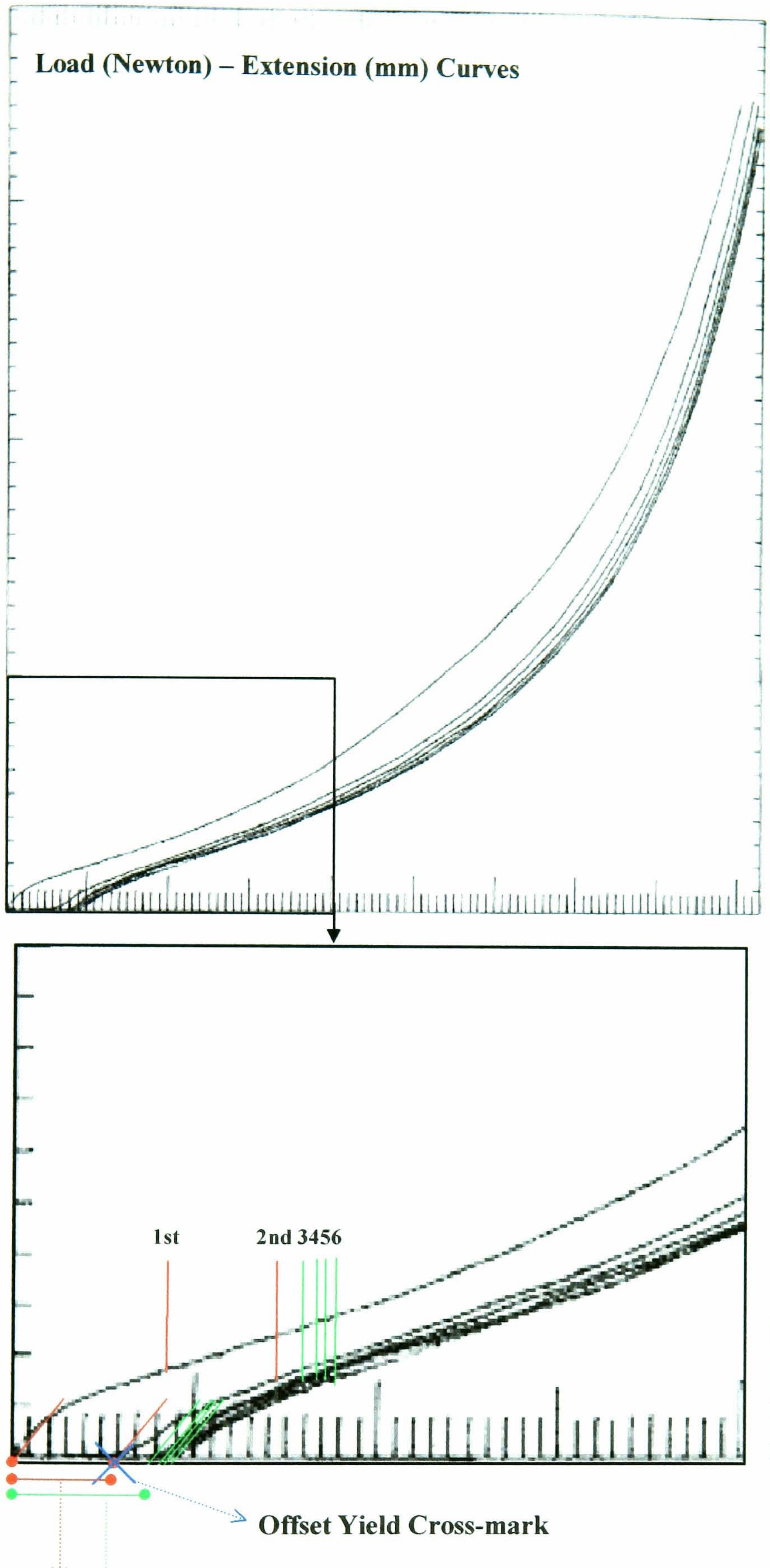
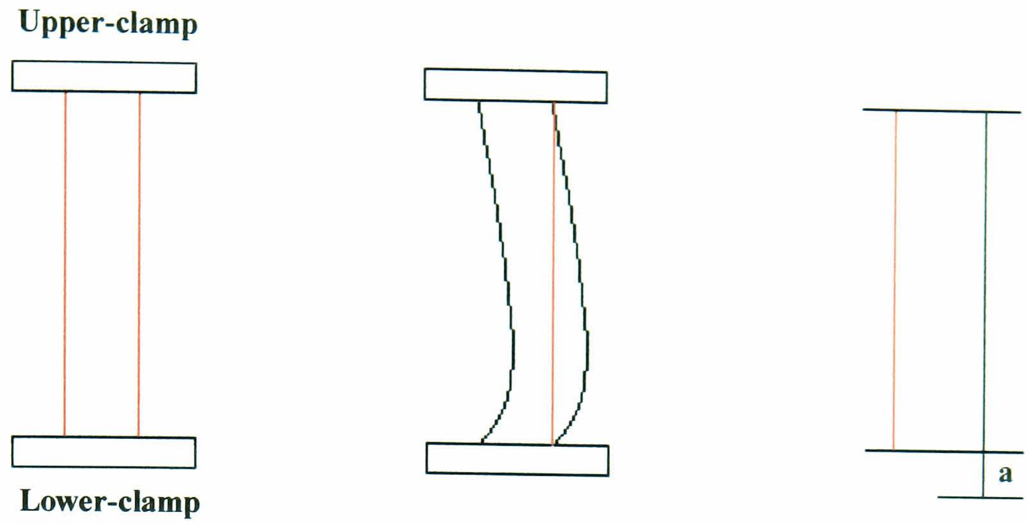


FIG. 4.2
Load-extension curves of the fabric which was repeatedly stretched

The 1st maximum residual extension amount appeared at the 2nd load / extension curve. This was calculated by moving cross-mark (×) to meet the working point of load at the beginning on the second extension curve shown after completing the stretch and returned to its original state.

The 2nd maximum residual extension amount appeared at the 3rd load / extension curve after completing the 2nd repeated stretch test then returned to its initial gauge length, etc.



The pre-set initial gauge length (200 mm bench marks) and the initial length of test sample

The sample length was increased after completing the 1st stretch and returned to its initial gauge length (200 mm bench marks)

The length difference between the initial sample length and the returned sample length. There "a" was named residual extension.

FIG. 4.3 Fabric stretch and dimension change

As the terms defined in Figure 4.1 that calculations of fabric extension, residual extension and recovery are described below.

- Percentage Extension (%) $= 100\,(L_2 - L_1) / L_1$
- Percentage Residual Extension (%) $= 100\,(L_3 - L_1) / L_1$
- Percentage Recovery (%) $= 100\,(L_2 - L_3) / (L_2 - L_1)$

Where: L_1 is the original specimen length.

L_2 is the extended specimen length.

L_3 is the specimen length measured immediately after repeated stretching is calculated.

All measurements were accurate to the nearest 0.01 mm. The extension in length in each of three specimens was measured from each of three fabric grain directions. Also the available fabric stretch was calculated to the nearest 0.01%. The fabric samples were tested in weft, warp and 45°-bias directions, respectively. Three repeat tests for each direction of fabrics were carried out, and average values were obtained.

4.3.4 Determination of Extension and Recovery Properties of Woven Stretch Fabrics at a Range of Extensions

Fabric specimens with a gauge length of 200 mm were stretched at a speed of 200mm/min to a range of extensions: 5%, 10%, 20%, 30%, 40% or 50%, respectively and returned to the gauge length. This was repeated five times. The residual extension and elastic recovery were calculated as described in Section 4.3.3. The fabric samples were tested in three directions of weft, warp and 45°-bias directions respectively.

The term woven stretch fabric is usually restricted to fabrics, which not only stretch more easily with an extension of at least 10% but also recover well from stretching, that is, return quickly to their original dimensions. The Recommended Residual Extension (%) (Du Pont, 1976) were:

(1) Tailored Clothing: average residual extension not to exceed maximum 3.0%

(2) Tensioned Slacks: average residual extension not to exceed maximum 5.0%

(3) Sportswear (active and casual): average residual extension not to exceed maximum 4.5%

The garment type used in this work is the tailored clothing and the recommended limit of fabric residual extension is not to exceed maximum 3.0%.

4.4 Results and Discussion

4.4.1 Extension and Recovery Properties of Woven Stretch Fabrics at the Fixed Load

The fabric specimens with 200mm gauge length were stretched at a speed of 200 mm/min until a load force of 18N was reached. After repeatedly stretching five times, the percentage extensions for the fabrics A to M at 18 N load in warp, weft and 45°-bias directions are shown in Figure 4.4a. Then the load force was removed from fabrics, the extensions were recovered to some extent and the residual extensions were left. Figure 4.4b and 4.4c displays the results of percentage residual extension and the values of percentage recovery of the thirteen fabric samples. The exact values of the extension, residual extension and recovery are given on the top of the bars for weft and 45°-bias directions, because the extension and recovery properties in warp direction is less important than in weft and 45°-bias directions for pattern reduction or alteration. The extension and recovery properties for the thirteen fabrics are presented from the best to the worst one in Figure 4.4. It was found from Figure 4.4a that woven stretch fabric L has the highest extension in weft and 45°-bias directions among these thirteen fabrics, but its recovery is very poor and the highest residual extension was left (see Figure 4.4b and 4.4c). Hence fabric L is easier to be stretched (regarding softness) but it is poorer in recovery of the extended fabric dimension both in weft direction and in 45°-bias direction. As a result fabric L was found unsatisfactory for customer to wear although it contains 4% elastane at weft direction. Furthermore the extension value at the fixed load can not alone express the performance of woven stretch fabrics. Residual extension will vitally affect the patterns of the garments.

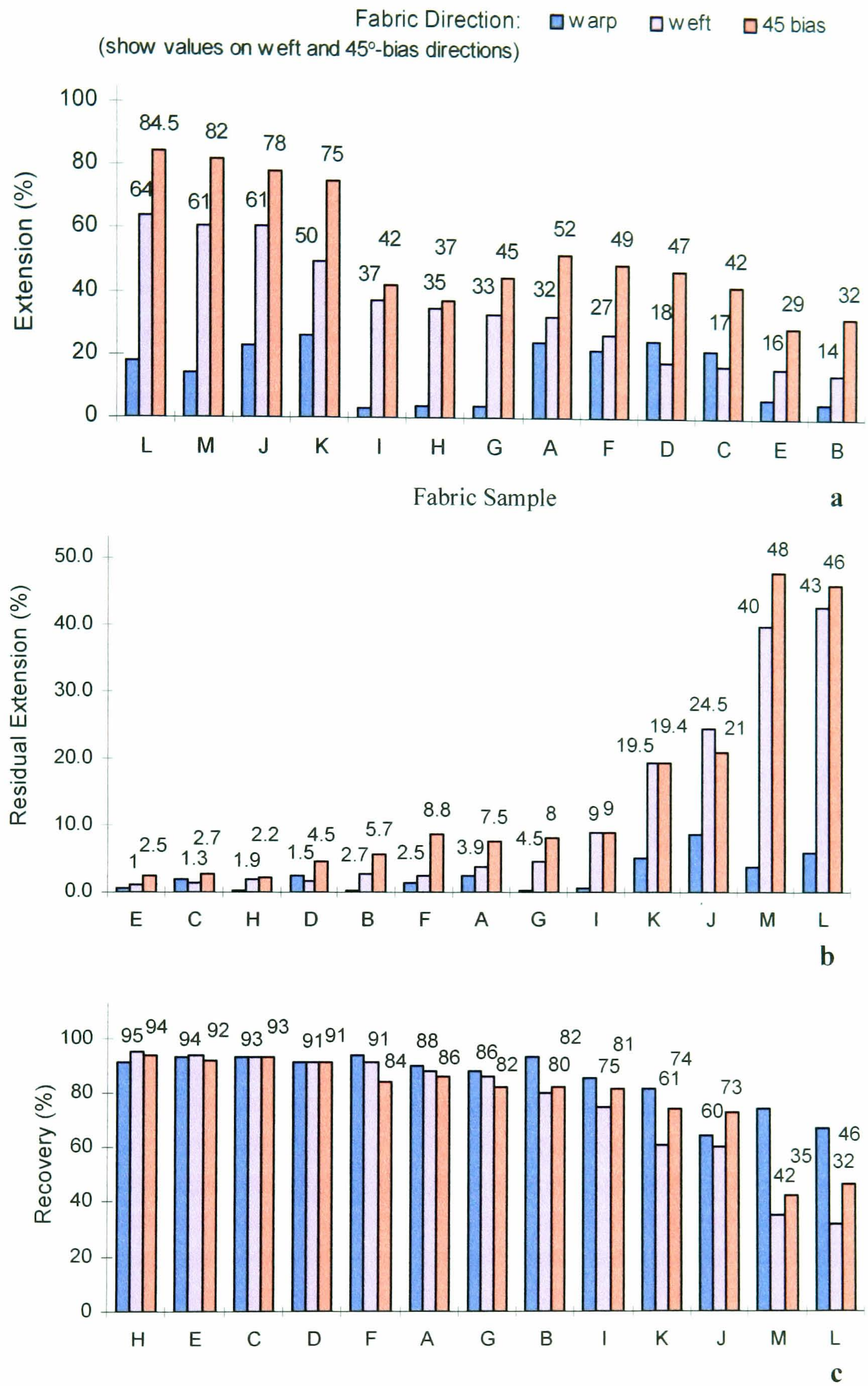


FIG. 4.4 a) Extension, b) Residual extension, c) Recovery of the thirteen woven stretch fabrics at the fixed load tensile test method were illustrated and ranged from the best to the worst

Therefore residual extension and elastic recovery will mainly be used to evaluate the performance of the woven stretch fabrics. It can be noticed from Table 3.1 that fabrics A, C and D have the same composition of blend fibres spun into similar yarn structure, but their woven structures are different (see Table 4.1). The extension of fabric A is greater than that of fabric D, which is greater than that of fabric C, but actually their percentage elastic recoveries are in reverse (Figure 4.4). The difference in extension and recovery property might be caused by their different weaving structure. A 2/2 twill fabric structure may be easier stretched than a 1/2 twill structure, but it may restrict the recovery to a small extent. There is no practical significant difference in the extension and recovery properties between plain and twill structures of woven fabrics.

Table 4.1 Fabric samples

Fabric Sample	Composition	Yarns		Weave	Ends per inch	Picks per inch	Twist Level (turns / inch)		Weight (g/m^2)
		Warp	Weft				Warp	Weft	
A	Wool 60% Polyester 36% Elastane 4%	Z, twist with elastane	Z, twist with elastane	2/2, 45° twill	75	85	30	30	285
C		S, twist with elastane	S, twist with elastane	Plain	60	60	25	25	190
D				1/2, 45° twill	66	64	25	25	225

Fabrics L and M were woven in the same kind of yarns but in different weaving structures (see Table 3.1 of Section 3.2 and Table 4.2) as well as Fabrics J and K. The differences in their weave structures was not significant to change their extension and recovery properties as shown in Figure 4.4. Comparing fabrics L and M and fabric I or fabrics J and K and fabric H, respectively, it can be found that the residual extension and recovery properties were influenced not only by the percentage of elastane but also the weave structure of the fabrics.

Table 4.2 Fabric samples I to M

Fabric Sample	Composition	Yarns		Weave	Ends per inch	Picks per inch	Twist Level (turns / inch)		Weight (g/m^2)
		Warp	Weft				Warp	Weft	
I	Polyester 48% Cotton 50% Elastane 2%	Textured yarn No elastane	Z, twist with elastane	3/1, 60° twill	82	54	textured	15	255
L	Polyester 35.4% Cotton 60% Elastane 4%	Textured yarn No elastane	Z, twist with elastane	Rib	127	48	textured	15	180
M	Polyester 35.4% Cotton 60% Elastane 4%	Textured yarn No elastane	Z, twist with elastane	Twill	127	48	textured	15	180
J	Polyester 94% Elastane 6%	Textured yarn No elastane	Low-twisted with elastane	Diagonal twill	127	48	textured	low (degree)	205
K	Polyester 94% Elastane 6%	Textured yarn No elastane	Low-twisted with elastane	Rib	127	48	textured	low (degree)	205
H	Polyester 98% Elastane 2%	Z, twist No elastane	Z, twist with elastane	Plain	105	50	20	15	190

It can also be noticed from Table 3.1 and Table 4.2 that there is no elastane spun in warp yarns for fabrics L, M, J, K, I, H, G, E and B. The former four fabrics (L, M, J and K) were still able to stretch to an extension of 20 to 25% at load force 18 N in warp direction, but their recovery properties were poor. On the other hand, the rest of the fabrics (I, H, G, E and B) were almost unable to be stretched at 18 N load force as they showed to have low extensions in Figure 4.4. Therefore elastane components might be the major factor for fabric to achieve both extension and recovery. According to the survey and the assessment in warp direction it was pointed out that the level of extension in warp direction might be significantly beneficial for garment comfort and fit but it was not affected on pattern reduction and alteration. Therefore the extension and recovery properties in the weft and 45°-bias directions are considered to be the most important. The results obtained from this fabric testing were found to be uncertain and insufficient to classify levels of extensibility and recovery of woven stretch fabrics for pattern modification and production. From measuring the extension and recovery properties at a fixed load, it was found that the fixed load may stretch the fabric to a high extension in the presence of high residual extension and poor recovery, or may not be able to stretch. The properties obtained are highly dependent on the applied force. On the other hand, a garment is subject to varying forces during wearing and body movement. This method may be useful for knitted fabrics but not for woven stretch fabrics because knitted fabrics usually extend much more easily than woven stretch fabrics under low load. Therefore the method of measuring the residual extension and recovery properties of fabrics at a fixed extension will be discussed in Section 4.4.2.

4.4.2 Extension and Recovery Properties of Woven Stretch Fabrics at the Fixed Extension

The thirteen fabrics (A to M) with a gauge length of 200 mm were repeatedly stretched five times at a speed of 200 mm/min to a range of extensions: 5%, 10%, 20%, 30%, 40% or 50%, respectively. The results of percentage residual extension and recovery of thirteen fabrics in three fabric directions are shown in Figures 4.5 to 4.10. Figure 4.5 shows the percentage residual extension of individual fabrics in warp direction after the samples were stretched to the different extension. Some fabrics started to tear at 30% of extension upwards, so their residual extensions were not shown in the chart. The residual extensions of fabrics increased with an increase in the degree of extension. The corresponding relationship is more clearly shown in Figure 4.6. It is obvious that the extension and recovery property of fabric I is very poor among these thirteen fabrics. The residual extensions for these fabrics started to increase beyond the extension of 20%.

Residual Extension (%) in Warp Direction

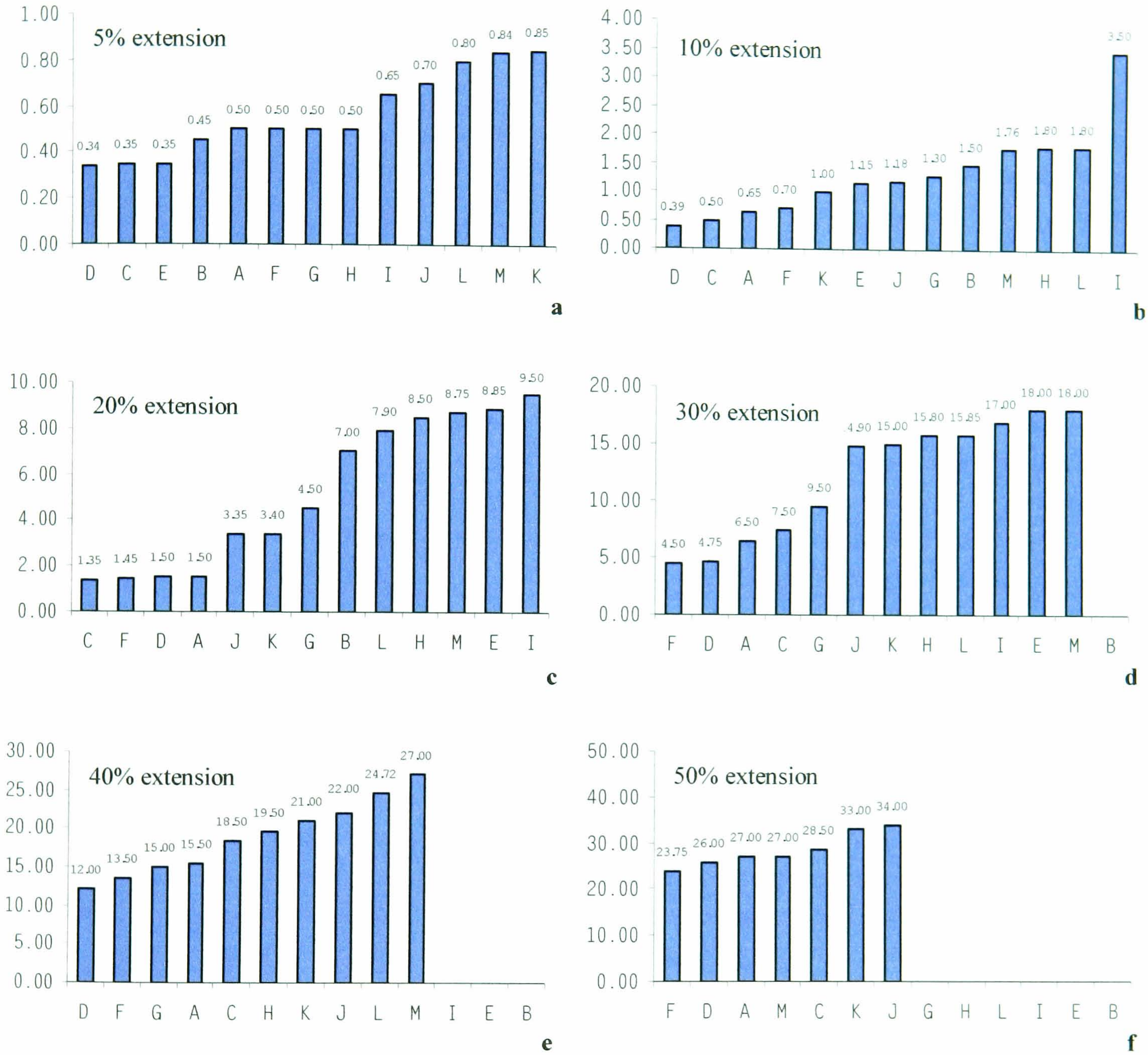


FIG. 4.5 Percentage residual extension comparison of the thirteen woven stretch fabrics A to M in warp direction stretched to the fixed extension rates 5% to 50%. The measured results displayed were arranged from the best value to the worst value of all fabrics.

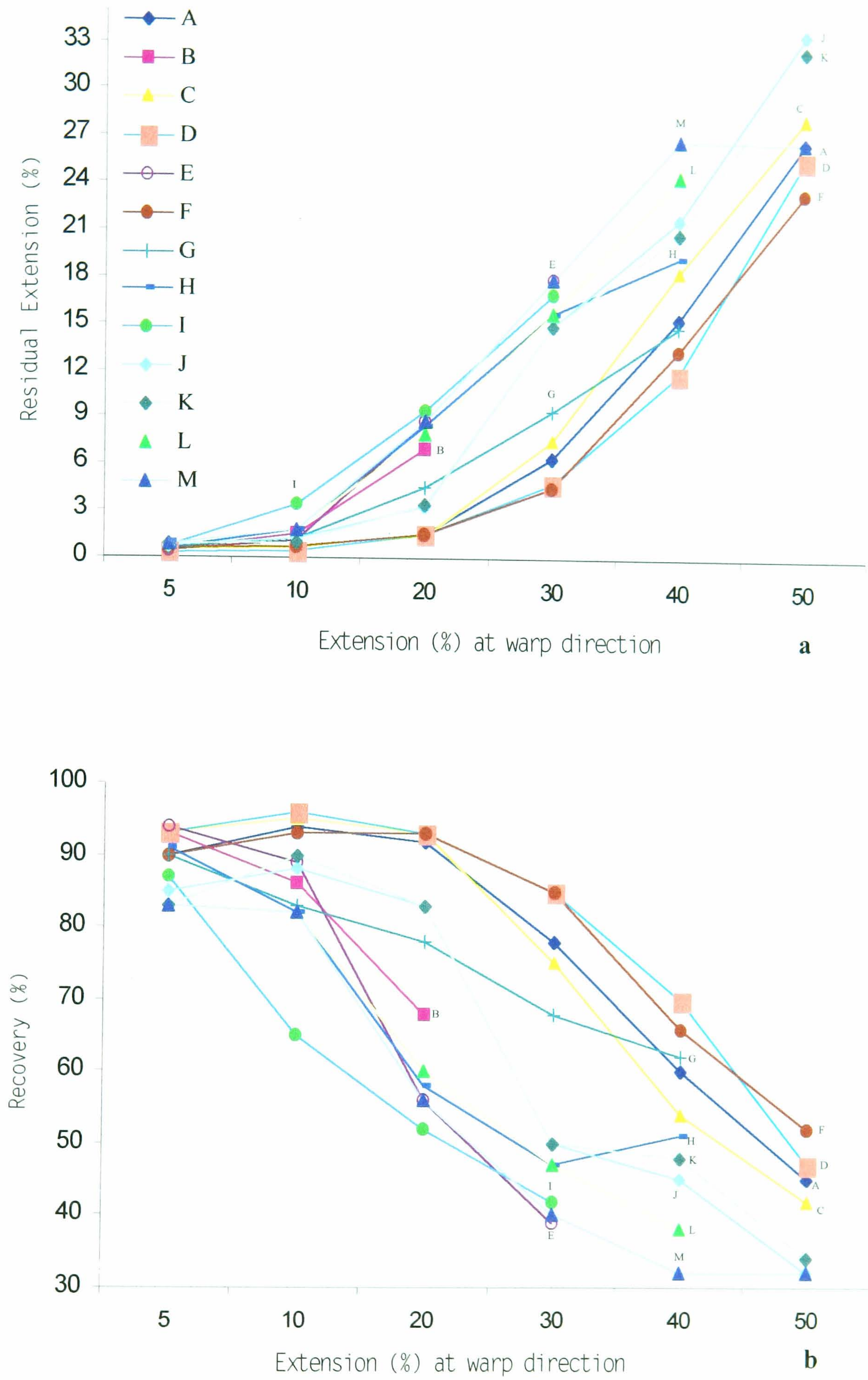


FIG. 4.6 Residual extension and recovery of the thirteen woven stretch fabrics at warp direction through the fixed extension rates from 5 % to 50 %.

Residual Extension (%) in Weft Direction

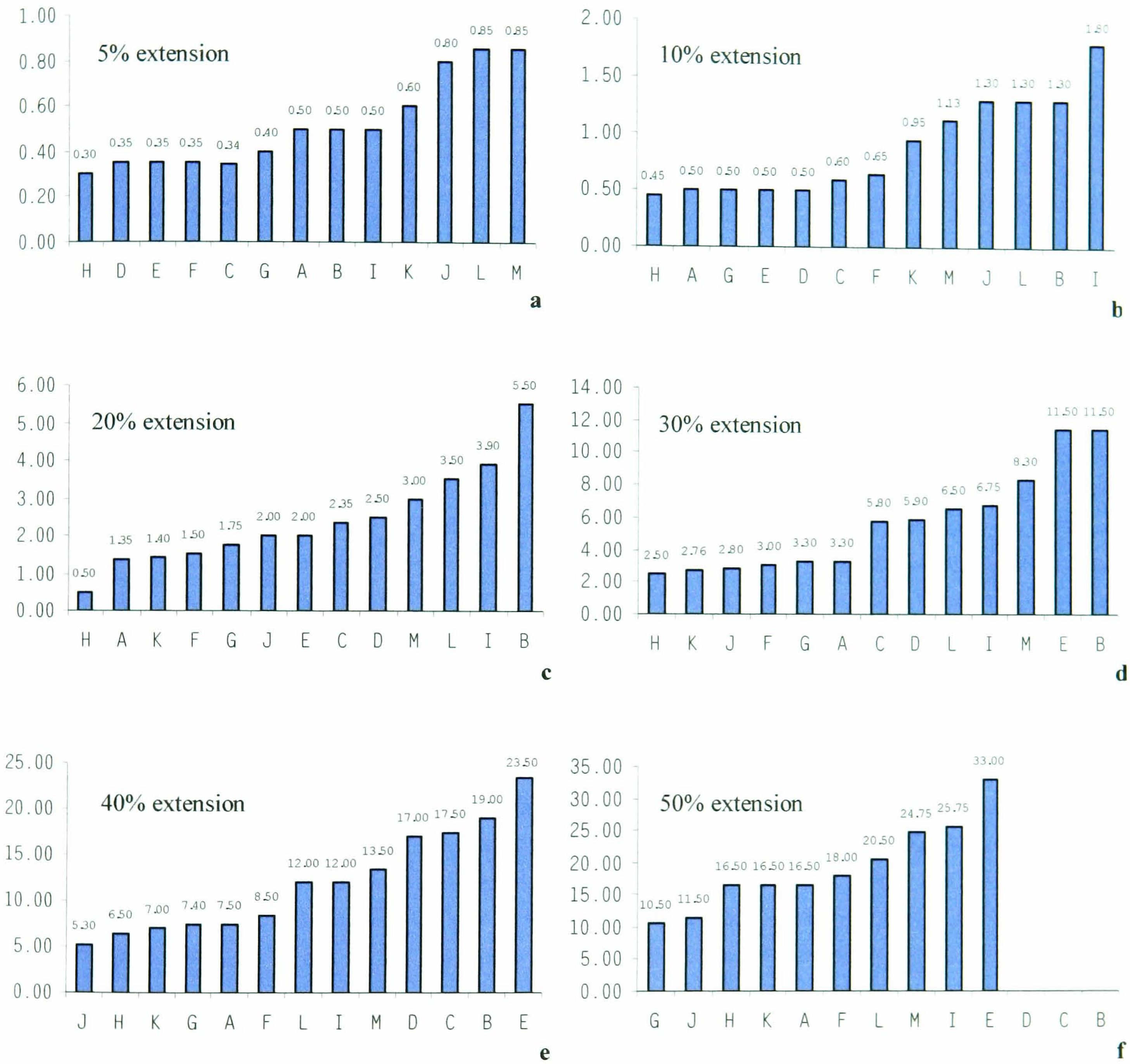


FIG. 4.7 Percentage residual extension of the thirteen woven stretch fabrics A to M in weft direction stretched to the fixed extension rates 5% to 50%. The measured results displayed were arranged from the best value to the worst value of all fabrics.

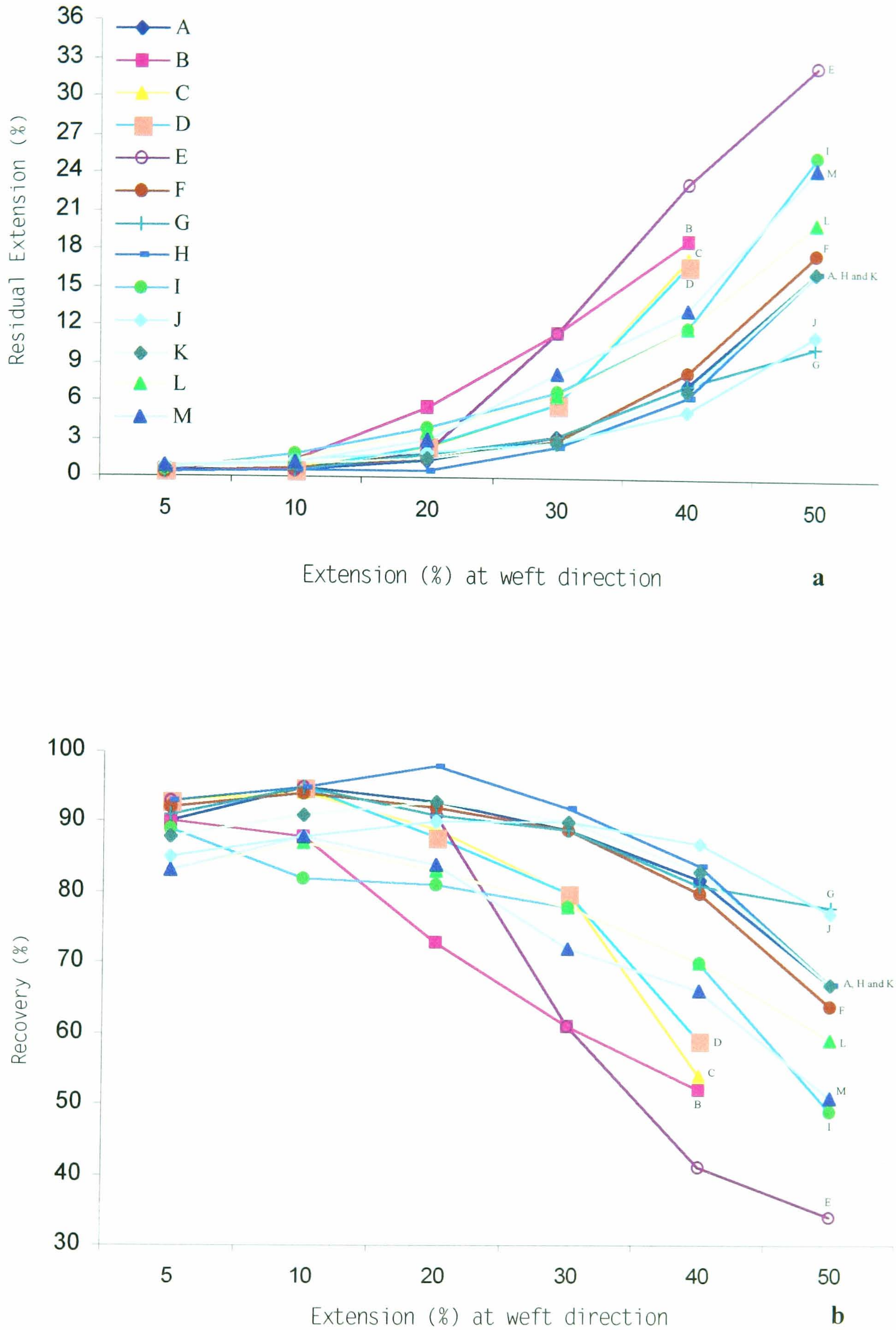


FIG. 4.8 Residual extension and recovery of the thirteen woven stretch fabrics at weft direction through the fixed extension rates from 5% to 50%.

Residual Extension (%) in 45°-bias Direction

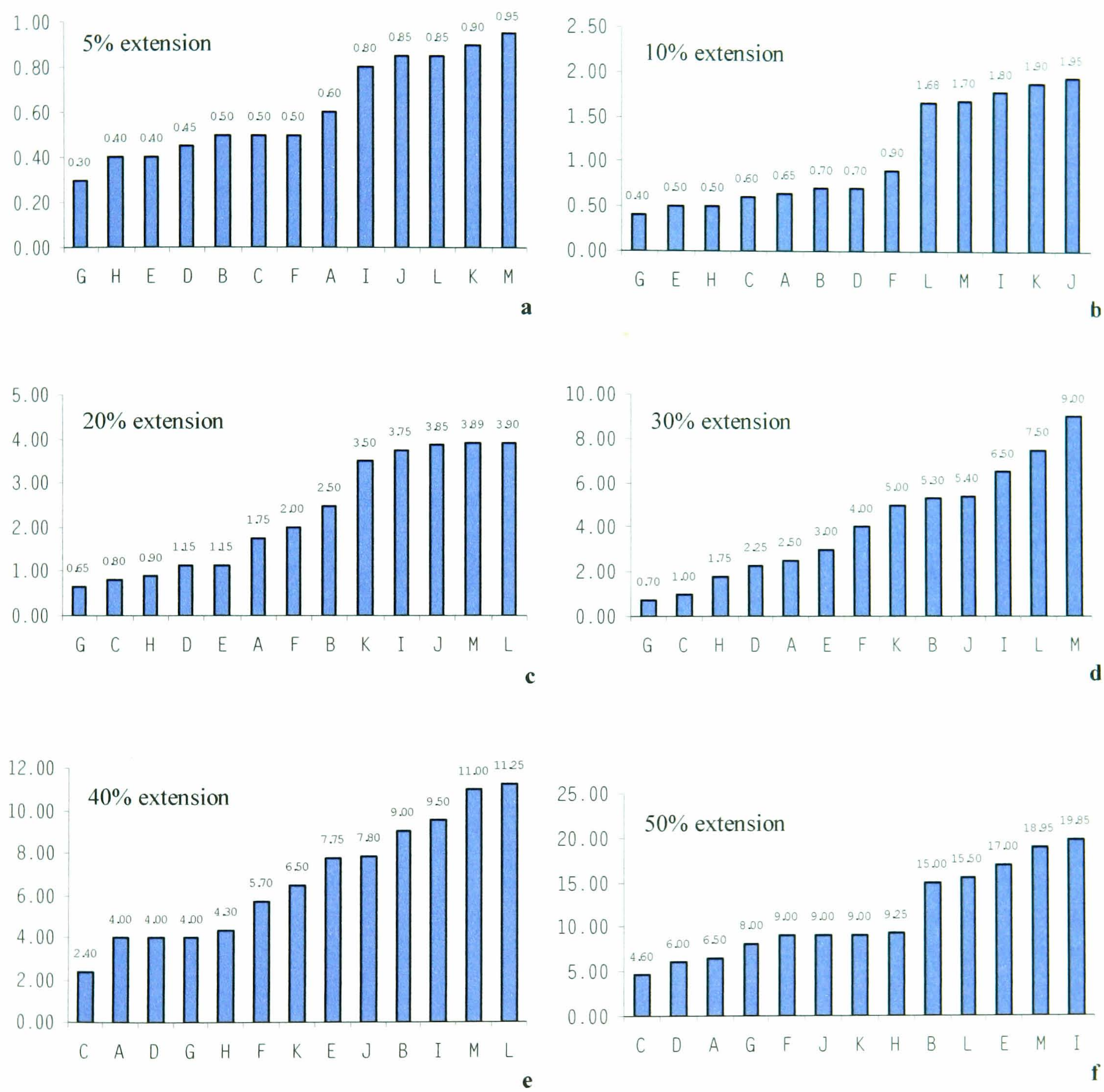


FIG. 4.9 Percentage residual extension comparison of the thirteen woven stretch fabrics A to M in 45°-bias direction stretched to the fixed extension rates 5% to 50%. The measured results displayed were arranged from the best value to the worst value of all fabrics.

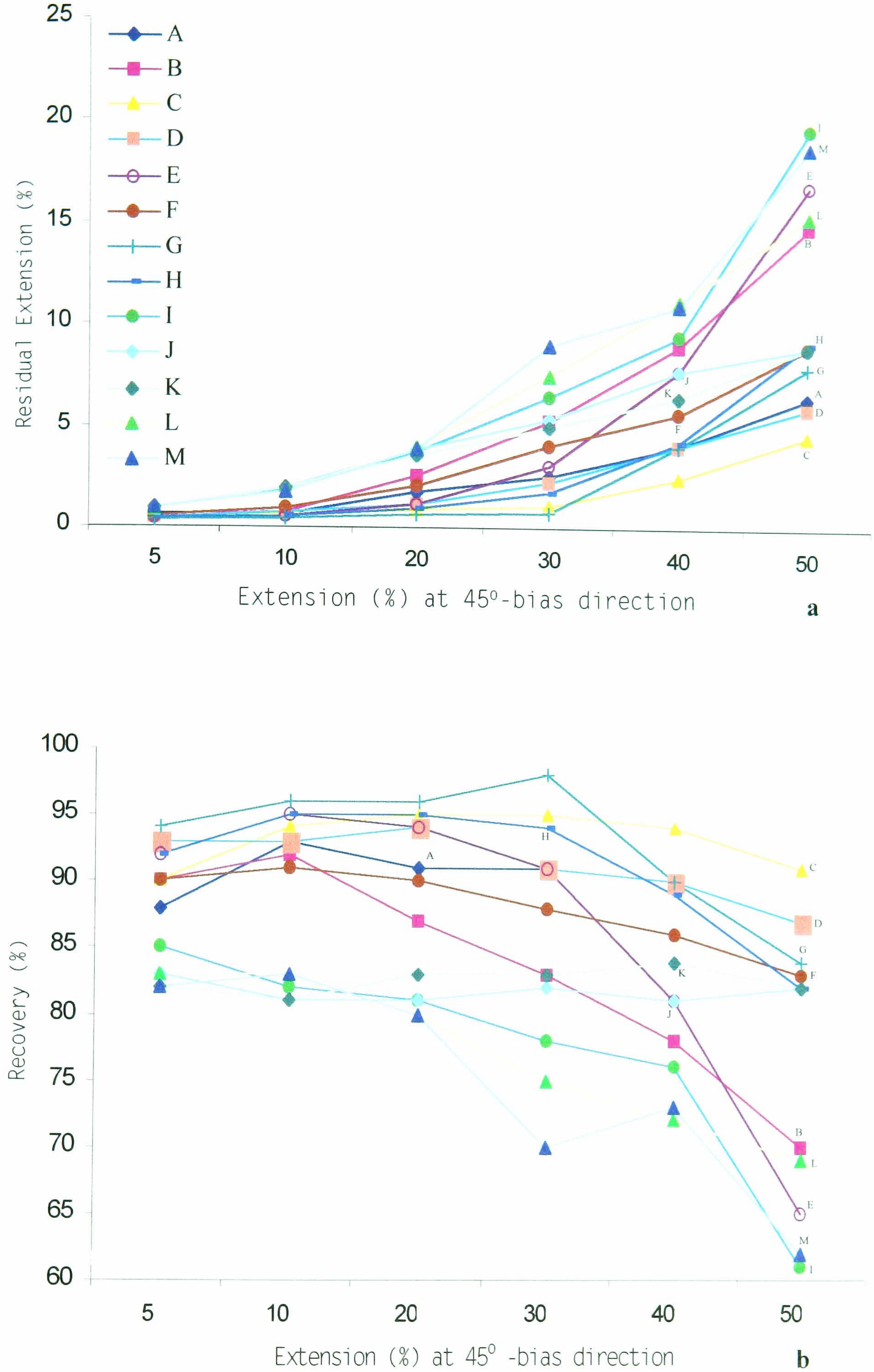


FIG. 4.10 Residual extension and recovery of the thirteen woven stretch fabrics at 45°-bias direction through the fixed extension rates from 5% to 50%.

Fabric K had good recovery with the extension of 20%, thereafter the residual extension is significantly increased. Their corresponding percentage recovery is shown in Figure 4.6b.

In pattern reduction or alternation, extension and recovery properties of woven stretch fabrics in weft direction is more important than that in warp direction. Figures 4.7 and 4.8 shows the percentage residual extension of individual fabrics in weft direction after the samples were stretched to the different extension. The weft yarns in all the fabrics tested in this present work contained elastane, therefore the extension and recovery properties of these fabrics in weft direction were generally better than that in warp direction. It can be seen in Figure 4.8a that the residual extensions for fabrics A, G, H, F, J and K start increasing at an extension of 30% upwards. Fabrics E, L, C, D, E and M start increasing at 20% extension upwards, and for fabric B at 10% extension upwards. Their corresponding recoveries are shown in Figure 4.8b. Previous work (Du Pont 1976) suggested that a woven stretch garment should meet the recommendation that tailored clothing should have an average residual extension not exceeding 3.0%. Therefore this level of residual extension is set for the present work, and assumes that the appearance of a woven stretch garment is not affected if this level is not exceeded during wearing. According to the data of extension and recovery of fabrics A to M at extensions: 5%, 10%, 20%, 30%, 40% and 50% shown in Figures 4.7 and 4.8, there is estimation in Table 4.3 for the maximum levels of extensions for the fabrics which can be stretched without exceeding 3% residual extension.

Table 4.3 The levels and values of the thirteen woven stretch fabrics at the recommended maximum residual extension 3%

Fabric Sample	Weft Direction	
	Extension (%)	Elastic Recovery (%)
I	10	82
B	10	88
L	10	87
A	20	93
C	20	89
D	20	88
E	20	91
M	20	84
G	20	91
H	30	92
F	30	89
J	30	90
K	30	90

The direction of stretch in garments has a significant effect on comfort, fit and performance. Lindberg and Disher (Lindberg, 1966; Disher, 1980) found that the most important direction is in the bias. Horizontal stretch gives the preferred balance of comfort, fit and performance in most garments and improves bias stretchability. Therefore the extension and recovery properties of the thirteen fabrics in 45°-bias fabric directions will be discussed. Figure 4.9 shows the percentage residual extension of fabrics A to M in 45°-bias direction at individual extension from 5% to 50%. It was found that no breakage of fabrics occurred even at the highest extension of 50%. The extension and recovery properties of these woven stretch fabrics in 45°-bias direction are better than that in weft direction especially at higher extension. Figure 4.10a shows the relationship between residual extension of fabrics in 45°-bias direction and the extension at which fabrics were stretched. Almost all of the fabrics still had lower residual extension at 20% extension, thereafter the residual extensions of fabrics increased at a different rate. The corresponding recovery results are shown in Figure 4.10b. It can be seen that fabrics can be divided in two groups according to their recovery levels at extensions between 5% to 20%. The percentage recovery of fabrics J, K, I, M and L were lower than that of the rest of the fabrics. Only fabric K has a constant level of recovery at varying range of extension. According to the data of extension and recovery of fabrics A to M (Figures 4.9 and 4.10), the maximum levels of extensions for the fabrics which can be stretched in 45°-bias direction without exceeding 3% residual extension was estimated. The results are given in Table 4.4.

Table 4.4 The levels and values of the thirteen woven stretch fabrics at the recommended maximum residual extension 3.0%

Fabric	45°-bias Direction	
Sample	Extension (%)	Elastic Recovery (%)
I	10	82
J	10	81
K	10	81
L	10	83
M	10	83
B	20	87
F	20	90
E	20	91
A	30	91
D	30	92
G	30	98
H	30	94
C	40	94

4.4.3 Discussion of Woven Stretch Fabric D and Control Woven Fabric S

According to the extension and recovery properties of woven stretch fabrics in Section 4.4.2, woven stretch fabric D will be selected for further pattern investigation, while woven fabric S will be used as reference for comparison. Therefore the extension and recovery properties of woven fabric S was also determined. Their results were shown in Figure 4.11.

Fabric D was a woven fabric containing 4% elastane in both warp and weft directions but fabric S did not. Nevertheless the fabric components of both fabrics come close (see Table 3.1). Figure 4.11 shows that fabric D has much better stretch and recovery properties than fabric S concluded under the fixed extension tensile test through three fabric directions. The residual extension amounts of fabric S and fabric D were close to each other at the 5% extension rate but thereafter they were very different in weft direction as shown in Figure 4.11c. The calculated results of both fabrics at 45°-bias direction show big differences from the beginning at the 5% extension rate up to the 50% rate. Of course the recovery values of both fabrics were assessed upon the amounts of their residual extension. Therefore it is shown that woven fabric S was poorer in fabric stretch and recovery properties than fabric D and would be much easier to be distorted especially in bias direction.

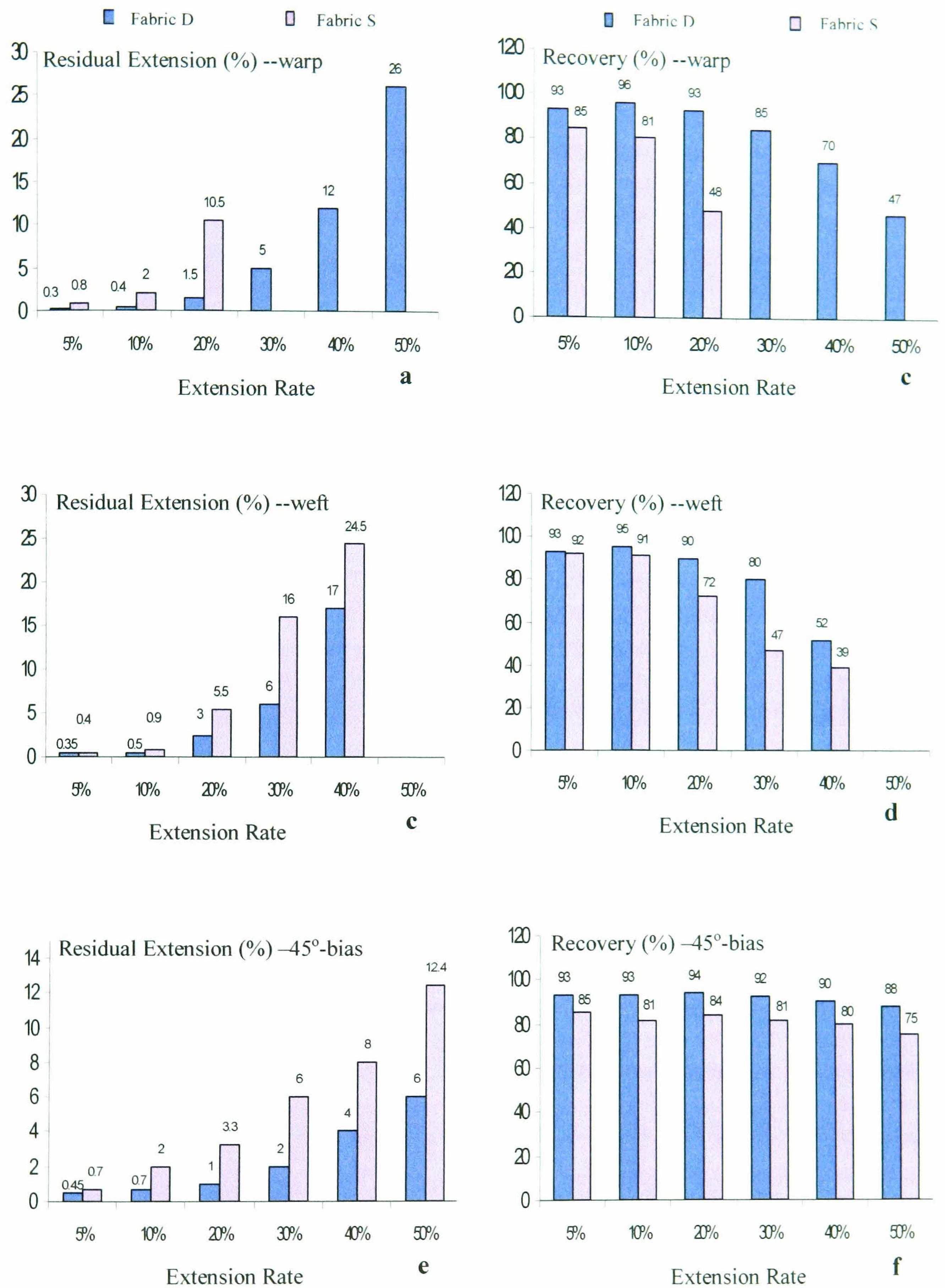


FIG. 4.11 Comparisons of residual extension and recovery of fabric D and S at three fabric directions through the fixed extension rates from 5% to 50%.

4.5 Conclusion

Extension and recovery properties of thirteen woven stretch fabrics at the fixed load and fixed extension were determined respectively using Instron tensile tester. These properties are highly dependent on the combined characteristics of fabric structure, yarn and fibre properties. It was found that the residual extension and recovery properties were influence not only by the percentage of elastane but also the weave structure of the fabrics. A 2/2 twill fabric structure may be easier stretched than a 1/2 twill structure, but it may restrict the recovery to a small extent. There is no practical significant difference in the extension and recovery properties between plain and twill structures of woven fabrics.

From the results obtained, it was shown that the fixed load tensile test method is unsuitable for predicting fabric stretch and recovery properties of woven stretch fabrics. The fixed extension tensile test method was found to be more suitable.

In order to deal with the problem of garment distortions while a garment (fabric) is worn and is subjected to repeated body movements, the repeated tensile test was applied to simulate a wearing action. The extension and recovery of woven stretch fabrics under repeating stretch to the certain range of extensions were determined. According to their residual extensions, the acceptable extension levels for these woven stretch fabrics were obtained for the use in pattern reduction and alteration.

5

DEVELOPMENT OF GARMENT PATTERN FOR WOVEN STRETCH FABRIC

CHAPTER 5

DEVELOPMENT OF GARMENT PATTERN FOR WOVEN STRETCH FABRIC

5.1 Introduction

From the previous chapters, the stretch and recovery properties of various woven stretch fabrics have been measured. According to their residual extensions, the extension levels for these fabrics were determined. Woven stretch fabric D will be selected for further pattern investigation, while woven fabric S will be used as reference for comparison. Because the woven stretch fabrics were created to offer customers the opportunity to wear tailored fitted garments and still have comfort during body movement, the garment pattern for woven stretch fabrics will be developed by considering major requirements for body movement to produce a better fitted shape. The pattern reduction will be scientifically carried out according to their acceptable extension levels of Fabric D. Garments made from fabrics D and S from a tailored pattern and on altered pattern, respectively, will be compared and evaluated.

5.1.1 Objectives

The aims of this chapter are to develop a suitable garment pattern for woven stretch fabric to fit the body shape and to meet the requirement of body movement. The pattern development or alteration will be carried out on the base of the traditional princess-line dress pattern, which is commonly made up in woven fabrics. The stretch and recovery properties of woven stretch fabrics determined in Chapter 4 will be taken account for pattern reduction.

5.1.2 Previous Developments of Garment Patterns and Construction

A basic pattern block is used to transform body measurement into a pattern that can be manipulated to produce different garment styles. It is usually constructed on paper. The pattern block can be based on average body measurements taken from size surveys, or it can be produced from a customer's own personal body measurement and requirements.

The clothing industry uses different pattern blocks for woven fabrics and knitted fabrics. For woven fabrics an extra amount (known as ease) is added to the measured size for allowance of body movement. In the case of knitted fabric pattern blocks the ease can be largely ignored (or reduced) as the inherent stretch properties of the fabric allows for body movement. There are four basic pattern blocks, which are suitable for different types of fabrics.

(1) Woven fabric

(2) Woven stretch fabric

(3) Jersey garment (knitted fabric)

(4) Knitwear

A woven fabric garment can be a tailored garment or soft-tailored garment, which is composed of ease, line, grain, balance and set. These elements have to be designed into the pattern construction through manipulation of the pattern block to produce a 3D garment, which will accommodate body bulges in a flattering manner. Tailored garments (made-to-measure) are mass produced products, and soft tailored garments are not as structured and tend to be more casual style. The difference between tailored garments and soft tailored garments is that a tailored garment is produced based on the customer's individual body measurement and so is more close fitting to the customer. Therefore the body measurement of a soft-tailored garment is mostly based upon size surveys from the local country. Pattern blocks of tailored garments are slightly different but fundamentally the base of pattern construction theory are the same as shown in Figure 5.1 (Miyoshi, 1985). Figure 5.1 illustrates the fundamental pattern construction process from two-dimensional fabrics to a three-dimensional garment. This is used for all tailored garments such as woven, woven stretch, non-woven and knitted garments. The manufacturing techniques and equipment used to generate a garment can be different. It depends on the costs that manufacturers wish to spend and relates to the target market and garment quality that they wish to have.

A jersey garment usually requires extra ease to meet body movement, but this requirement can be provided by the inherent stretchability of the fabric. Therefore, jersey wear can accommodate body bulges and body shapes easily and comfortably without ease, darts. The garments can be close-fitted, semi-fitted or loose-fitted depending on the fabric stretch and recovery properties and the garment design for their end-use, as shown in Figures 5.2a and 5.2b. Some close-fitted jersey garments can be made much smaller than the original pattern size. In the above figures, three jersey garments in the same dress style were made up in different knitted fabrics which have different levels of fabric extension and recovery properties. These jersey garments were all designed to conform to the body shape or to provide better stretchability for body movement. Hence the pattern blocks of the jersey garments were very different and the various styling details were reflected into their pattern designs. Figure 5.3c shows the pattern blocks of close-fitted jersey garments and loose-fitted jersey garments. The pattern form can be based on a rectangular shape or the body shape and depends on the garment quality as shown in Figures 5.4a and 5.4b. This is not only because the shape of the pattern block was different but it was also related to the time and cost spent on generating garments.

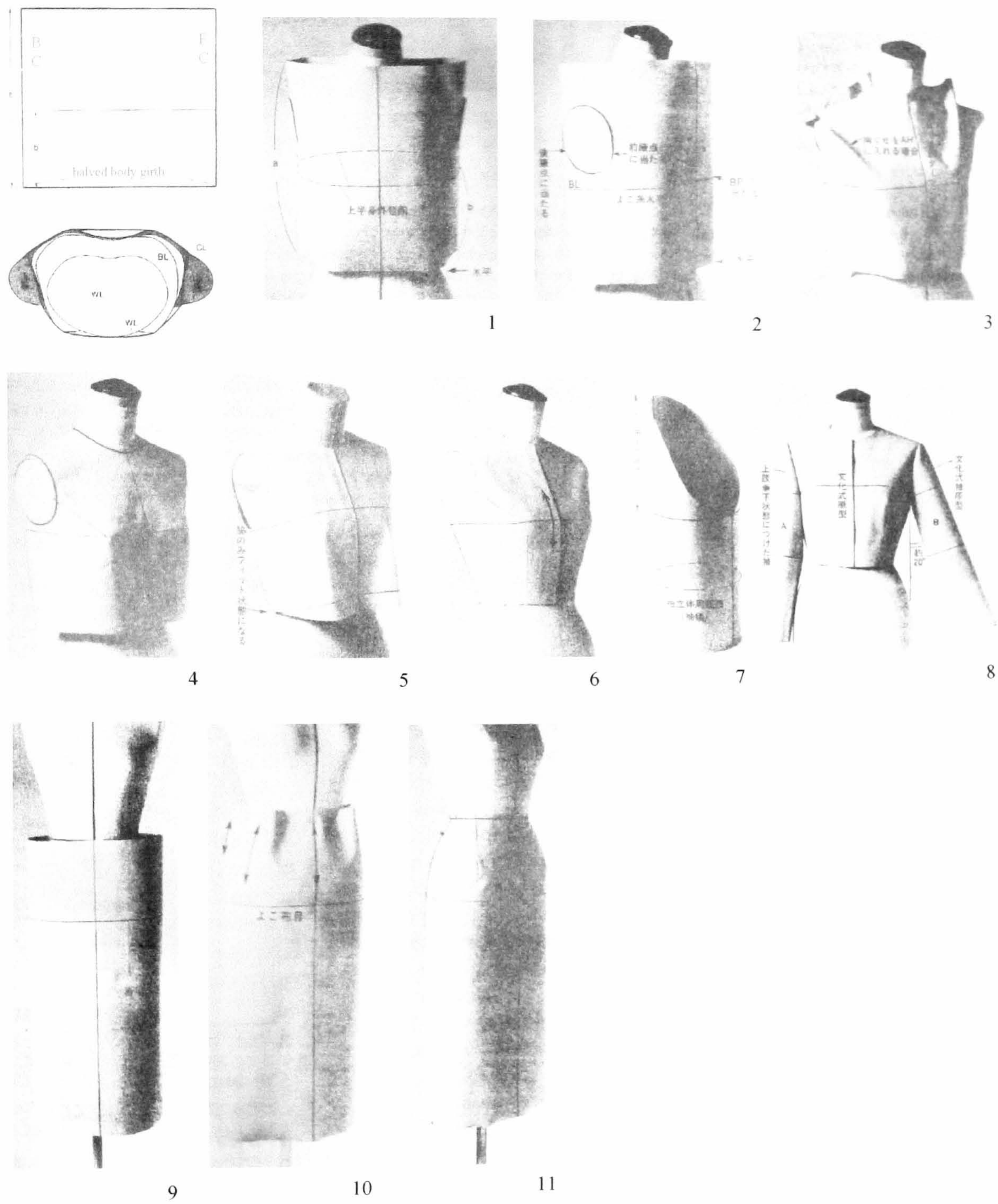


FIG. 5.1 Pattern generation process from two-dimensional fabrics to be three-dimensional garment form (Miyoshi, 1985)

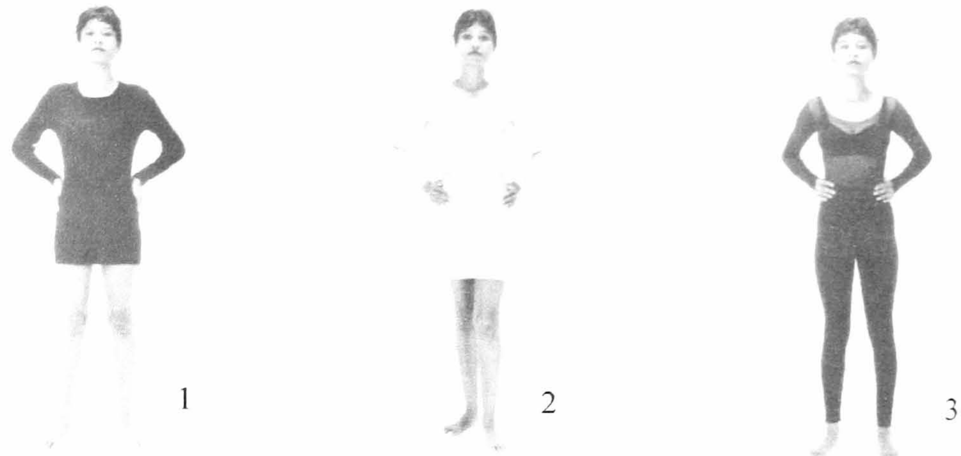


FIG. 5.2a These jersey garments have the same dress style but have been produced using of different knitted fabrics (Aldrich and Aldrich, 1996)

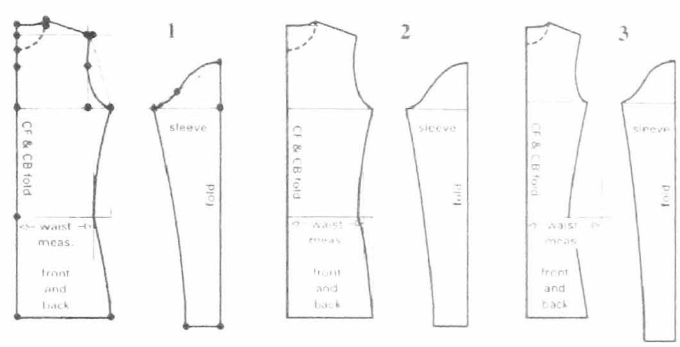
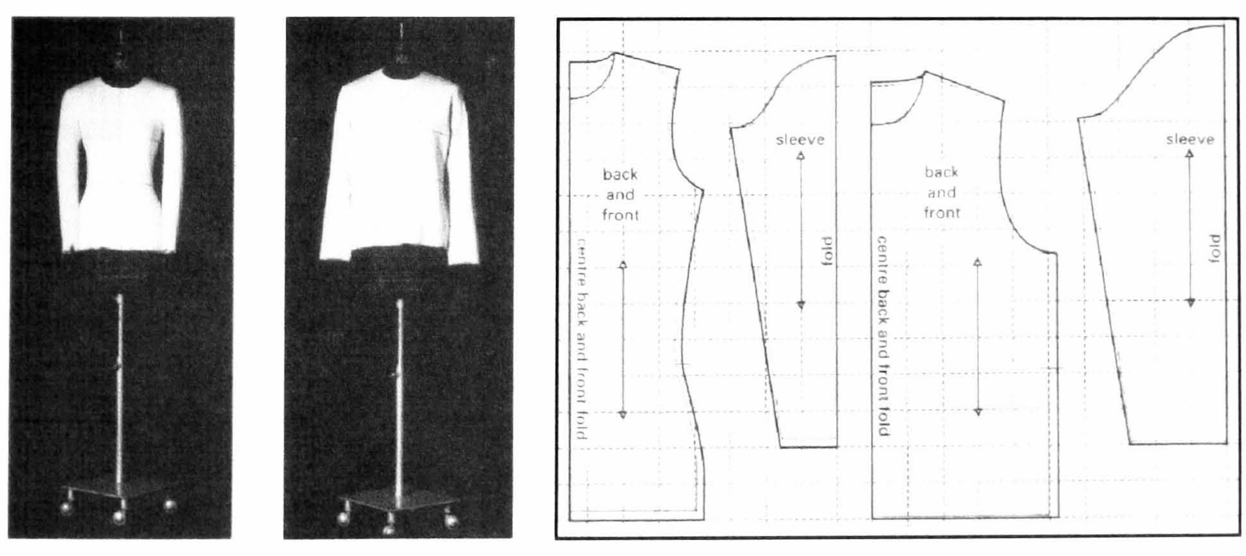


FIG. 5.2b Three pattern blocks designed for three jersey garments (see Figure 5.2a).



a. Close-fitted jersey garment

b. Loose-fitted jersey garment

c. Pattern blocks of close-fitted jersey garment and loose-fitted jersey garment

FIG. 5.3 Jersey garments and their pattern blocks

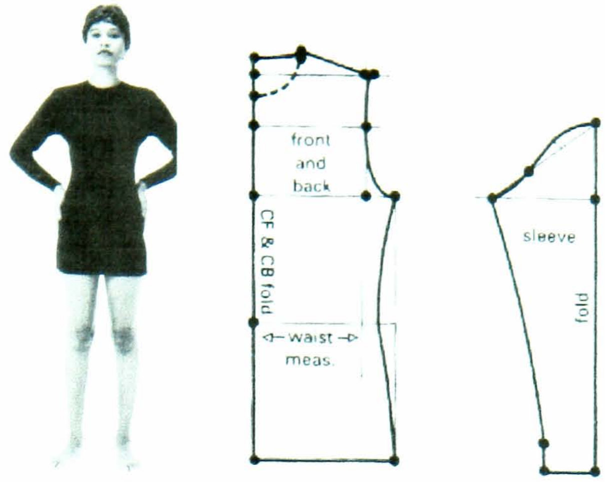


FIG. 5.4a
Body shaped pattern block and its dress form (Aldrich and Aldrich, 1996)

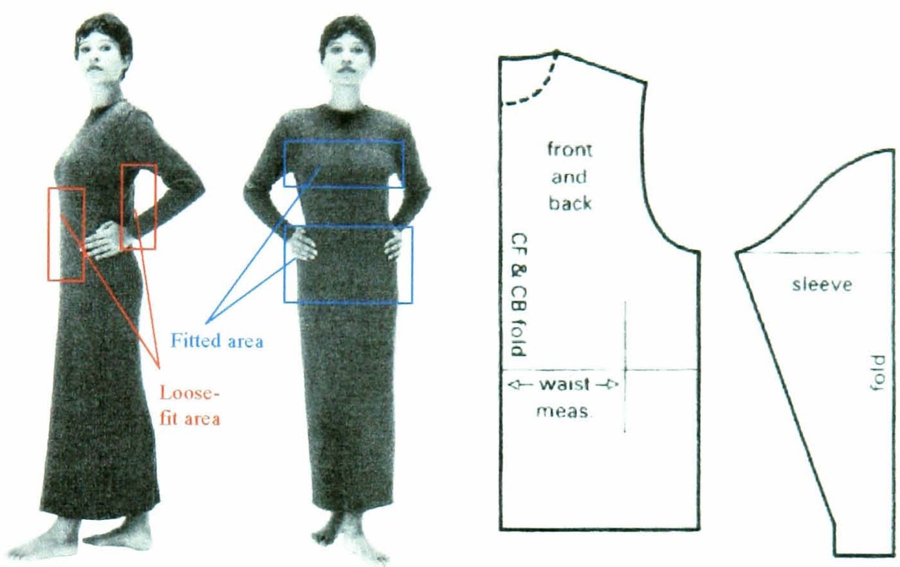


FIG 5.4b
The rectangular pattern block and its dress form

Knitwear and Jersey garments are a category of knitted garments and their fabric characteristics are very similar. Both of them have better stretch and recovery properties. Knitwear is usually designed to be worn casually although it can be fitted to the body easily. For the same reason as jersey garments, knitwear mainly depends on the level of fabric percentage extension and recovery. Although the fabric stretch and recovery properties of both garment types are similar, the pattern construction of knitwear is different with jersey garments. The basic pattern blocks for knitwear are usually looser than woven garments and jersey garments except when there is a specific requirement for a close-fitted look. Four basic methods exist for the generation of knitwear garments, these are fully cut, knitted piece goods, cut stitch shaped, fully fashioned and integrally knitted as shown in Figure 5.5.

(1) Fully cut knitted piece goods: these are lengths of fabric from which garments are cut for mass

(2) Cut stitch shaped: knitting of made to size portions of fabric, with some shaping introduced by changing of stitches

(3) Fully fashioned: knitting shaped portions of fabric in the flat

(4) Integrally knitted: the shape is generated in the round during knitting, leaving little or no seaming

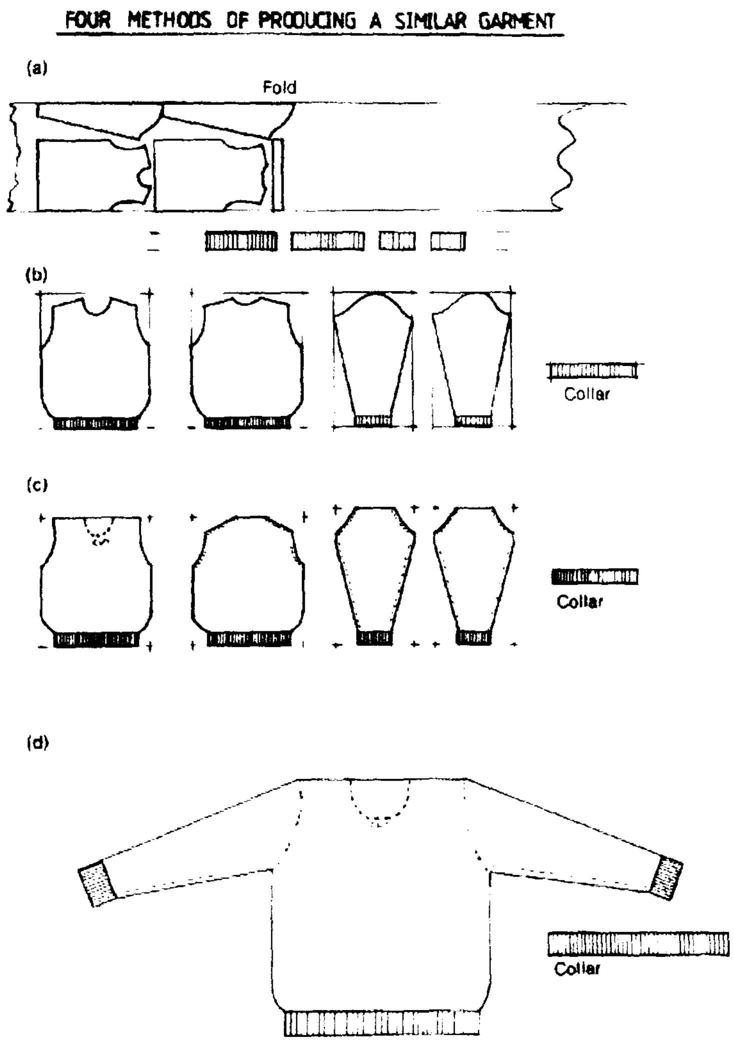


FIG. 5.5 Four methods of producing similar knitwear: (a). fully cut, (b). cut stitch shaped, (c). fully fashioned, (d). integrally knitted.

The term **fully cut** describes the processes most akin to making garments from woven fabric. Garments are cut from piece goods fabric, laid up (spread) on to cutting tables. All parts of the garments other than the trims are cut from the lay. Each garment piece has all edges cut, hence the term 'fully cut'. **Cut stitch shaped**: the majority of knitwear is produced by this method, together with a very small production of ladies' vests. The general method involves knitting rectangles of fabric related to the size of the portions of the garment to be made. The pieces, known as 'blanks', have the lower edge of the fabric sealed with a structure known as a 'welt' that prevents laddering and distortions of waistbands and cuffs. The term 'stitch shaped' derives from different stitch structures within the length of the blank that distort it from the rectangle into a shape associated with the human body. **Fully fashioning** is the process whereby portions of a garment are shaped at the selvages by progressively increasing or decreasing the number of loops in the width of the fabric. Such narrowing and widening produces the shape of a piece of garment that would otherwise be generated by cutting. Full fashioning has two obvious advantages over the two previously described categories of garment making:

(1) there is little or no cutting waste

(2) the edges of the garment pieces are sealed and not liable to fraying, so can be joined by simple non-bulky seams.

Fully fashioned garments are usually associated with knitted outerwear of a particular classical type and with a particular type of machinery. **Integrally knitted garments** are those that are essentially knitted in one piece with little or no seams. The archetypal example is the beret, which is knitted sequentially in a series of triangles, leaving the beginning and the end to be joined into a three dimensional shape.

5.1.3 Pattern for Woven Stretch Garment

Woven stretch garments have better stretch and recovery properties than woven garments but less than jersey garments. Modification and development of the pattern blocks of woven garments and jersey garments can achieve the pattern block for woven stretch fabric. The pattern block of woven stretch fabric is constructed depending on the level of fabric percentage extension and recovery. Woven stretch garments can not accommodate body bulges and shape as inherently as jersey garments. Hence the basic pattern block of woven stretch fabric has to contain the necessary ease, dart, line, balance and set to provide body shape and allow for body movement and comfort. If the woven pattern blocks were used for woven stretch fabrics without modification and development, the resulting garment would be comfortable to wear. Manufacturers realised that reducing the pattern for woven stretch fabrics could be used to offer customers a better fitted garment while still retaining most of the advantages in comfort properties. Therefore, a woven stretch garment can offer consumers a better garment quality and shape than a tailored fitted woven garment by applying appropriate pattern reduction and alteration. However, currently, most manufacturers use woven pattern blocks to produce woven stretch garments or reduce the pattern block by the trial and error system to give the desired fit. Pattern development is based on a basic pattern block at the beginning. Three requirements for pattern development and modification have to be considered at the beginning of the process.

(1) Comfort of body movement

(2) Body shape (type) and size

(3) Method of pattern construction

A basic pattern block has to comprise of all the elements allowed to obtain an accurate pattern block for further pattern generation. Generated garments have to allow wearers to make movements comfortably. Pattern makers usually achieve this by adding ease and darts, formed-lines and shapes, etc. to accommodate the 3D body shape. Loose-fitted pattern blocks allow for very comfortable movement, as well as hiding rather than accentuating the shape of the figure, but they may not be very practical in certain occupations. A better garment pattern construction must conform more or less to the body shape. This can only be achieved either by using soft fabric material to drape closely to the body or by shaping the fabric into a curved surface. For rigid fabrics, shaping can be achieved by cutting, sewing and shaping. during the pattern making process. Although the pattern construction of rigid fabric may be able to fit one body position, they become poorly fitted if the wearer moves or bends her arms or trunk. These kind of fabrics must buckle to accommodate the distortions as a result of movement and, because of this, pressure may be applied to localised areas of the body surface. If this pressure is significant, discomfort may ensue. To overcome these limitations, well fitted garments can be designed with ease added to enable movement and provide fullness to accommodate body distortions and garment restrictions. The term used in this work to add a required amount of ease to a basic pattern block to accommodate body movement is "ease allowance".

With so many influences involved it is not surprising that the ease allowance across the body girth varies so much, internationally from as little as 1 cm (Armstrong. 1995) to as large as more than 6 cm (Miyoshi, 1985). This was added into the halved (full 1/2 front and 1/2 back) bust girth size of pattern block. But it was found that 1cm ease allowance is too narrow for some garments (e.g., jacket and coat but necessary for close-fitted clothes such as underwear and formal dresses). The most logical choice for an economical ease allowance would seem to be about 5 cm (Gillian, 1997 and Ann, 1990, Margaret, 1968). Also, it is a preference for helping to simplify pattern making on deciding the girth size of pattern block, because the pattern construction is usually halved for pattern drafting. It was found that a 6cm ease allowance has the disadvantage, because it is too wide for regular body size. Therefore, an intermediate allowance of 5 cm was preferred for a basic pattern block as applied in many countries.

In this present work, this level of ease allowance (5cm) was selected to be added into the basic pattern block of woven fabric garment. Women's proportions are extremely varied. The Clothing Council's report shows that two women of equal hip girth size can vary to the remarkable extent of 12 inch in their bust measurement (Kunick, 1984). Consequently two women of equal bust girth size can be shaped quite differently. This illustrates why ready-to-wear garments cannot possibly fit all customers satisfactorily. Therefore variations of figure shape must be quite obviously incorporated into pattern construction which set out to meet the requirements of the consumer. Body figure types can be understood by viewing cross sections of body parts-buttocks, waist / abdomen, and chest / back as shown in Figure 5.6 (Armstrong, 1995). Body-figure deviations, if any, really do not matter when a personal-fitted pattern block is being developed as long as the measurements taken are accurate and all fitting problems are corrected when the garment is test fitted (toile proof). To provide a better pattern block an individual fitted pattern block of an appointed wearer should be better than that following a published size system (British Standard: 3666 women's wear, 1982) or to present a range of standard garments to fit the wearer. The accurate outcomes for pattern modification and development can be obtained.

ABDOMEN / TIGHT RELATIONSHIP

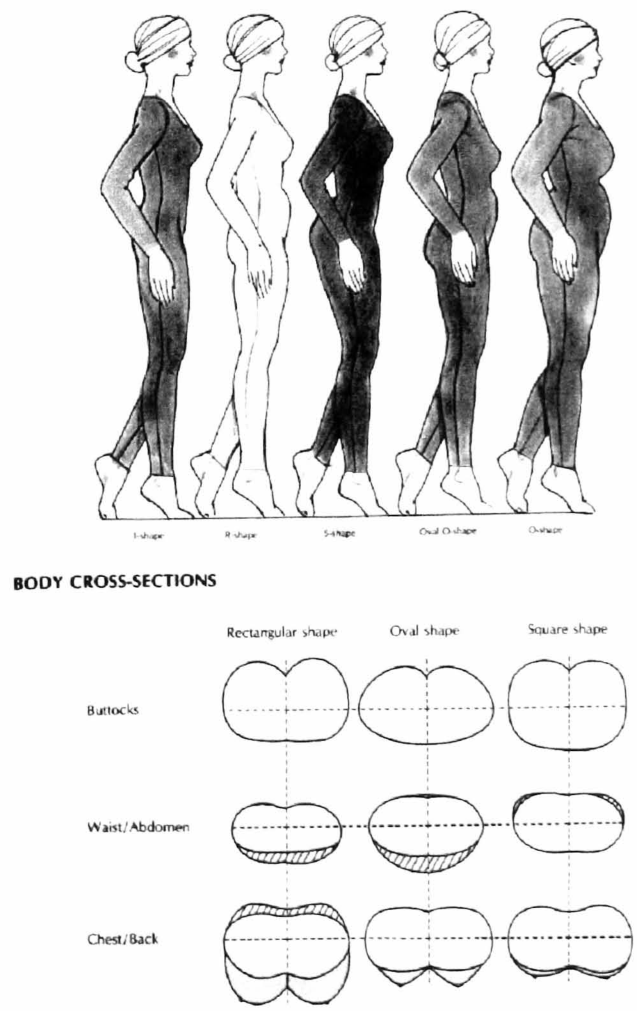


FIG. 5.6 Cross sections of body parts, buttocks and waist / abdomen, chest / back generally

Size measurements are a major factor in the development of the basic pattern block. As the considerations in figure shape, it was found difficult to use standard sizes

(BS: 3666, 1982) to construct the basic pattern block for the appointed model. Standard sizing systems world-wide were designed for economy by covering the maximum number of women with the minimum number of sizes. Unfortunately a standard size can be the accurate nominal size of a garment but a bad fit. Thereby any inaccurate size measurements of a specific wearer at the development stages can cause the failure to the pattern modification and development. Therefore it is necessary to construct an accurate basic pattern block for pattern development which is taken from a model's size measurements. Furthermore there is a difficulty in defining, for example, a size 14 because the British Standard does not specify particular body measurements for garment size, but offers a size range. It gives a scope of 4cm allowance between the minimum and maximum measurements of hip girth and bust girth. As a result in this project a basic pattern block based on the measurements of an appointed model will be performed through making the basic pattern block and the toile. All size measurements were taken using a standard tape measurement to measure the required measurements. Twenty-four body size measurements were taken from the appointed model and were used to construct the basic pattern block for a woven garment and twenty-seven body size measurements were taken from the same model and were used to generate five skin-fit pattern blocks for further pattern development.

The methods of pattern construction devised for this study – where garments were adjusted individually with several fittings – are unsuitable for the wholesale trade but accurate for pattern investigations, where accuracy is of paramount importance. Stretch garments demand a method of producing accurate pattern blocks without the need for basic adjustments. It is because the pattern makers prefer to model their pattern blocks on standard-sized mannequins. The skilful pattern maker can achieve good results by this method. All methods of pattern construction, however, are based on modelling. This is true even when any number of direct size measurements are taken and applied to a flat pattern draft. In woven garments, the modelling is identical as the toile is used to assess the fit and comfort properties. It was found much easier to use stretchable fabric than woven fabrics to get a proper fit and comfort through the direct modelling on a standard mannequin. Without the knowledge and experience gained from modelling on the human figure or standard mannequin, accurate size measurements could easily be misused. Modelling reproduces the three-dimensional pattern form by direct means, without which the pattern drafting would require an impractical and complex system of size measurements. Two types of pattern block were capably used to generate a new basic pattern block for woven stretch garments.

(1). The pattern block of well-fitted woven fabric garment was produced based on the tried and tested pattern construction theory to produce the basic pattern block from the body size measurements.

(2). The pattern block of skin-fitted jersey garment (knitted fabric) was obtained by applying the original idea of modelling the jersey fabrics upon the human figure (or the standard mannequin) for their customers.

The pattern modifications and developments for the study are described in the following sections.

5.2 Summary of the Process of Pattern Development for Woven Stretch Fabric in the Present Work

The necessity for pattern development for woven stretch fabric is to introduce the requirements of body movement into the basic woven pattern. The modification of the pattern was based on the reduction of the maximum required pattern for the body movement proportional to the stretch and recovery properties of woven stretch fabrics, which were obtained in Chapter 4. Figure 5.7 shows the pattern development process for woven stretch fabrics (Pattern B) in the present work. A basic pattern block of woven fabric was produced based on the current tailored pattern construction theory. 24 different body measurements were taken from an appointed model in a relaxed standing upright position. The basic pattern block was constructed by applying 24 body measurements with the required ease. A pattern block of a princess-line dress (Pattern A) was further produced based on the basic pattern block and modified to fit using trial and error.

Five typical body postures were defined for the investigation of pattern design. These five postures aim to take the major extended body movements into account to produce the desired pattern blocks of woven stretch garments. The pattern blocks for these postures were obtained from a skin-fit-knitted jersey garment, which the model was wearing. The reason for using the jersey garment rather than body skin was that jersey garment can be stretched easily to capture the stretched body size without ease addition, it includes considerations of necessary garment slippage and restriction. Different postures also show the body stretch in different ways and extents. Pattern blocks from the jersey garment for individual defined postures were obtained by determining 27 different body measurements. These five pattern blocks reflected the requirement of body movement. Then these pattern blocks were overlapped to form one pattern to meet the limits of all five postures.

The overlapped pattern block from the jersey garment in five different postures was combined with the basic pattern block (pattern A) from woven fabric by further overlapping. The maximum and minimum boundaries of the final overlapped pattern block were obtained. The maximum boundary was designed for pattern to meet the requirements of body movement especially in the defined five postures. The minimum boundary is designed for the patterns required to keep the desired garment shape without distortions, and also for comfort after the pattern reduction and alteration. According to the stretch and recovery properties of woven stretch fabrics, the level of pattern reduction and alteration from the maximum boundary was calculated. A new altered pattern block for woven stretch fabric was generated as shown in Pattern B in Figure 5.7. The new pattern was able to fulfil the requirements sufficiently of good fit and comfort for body movements.

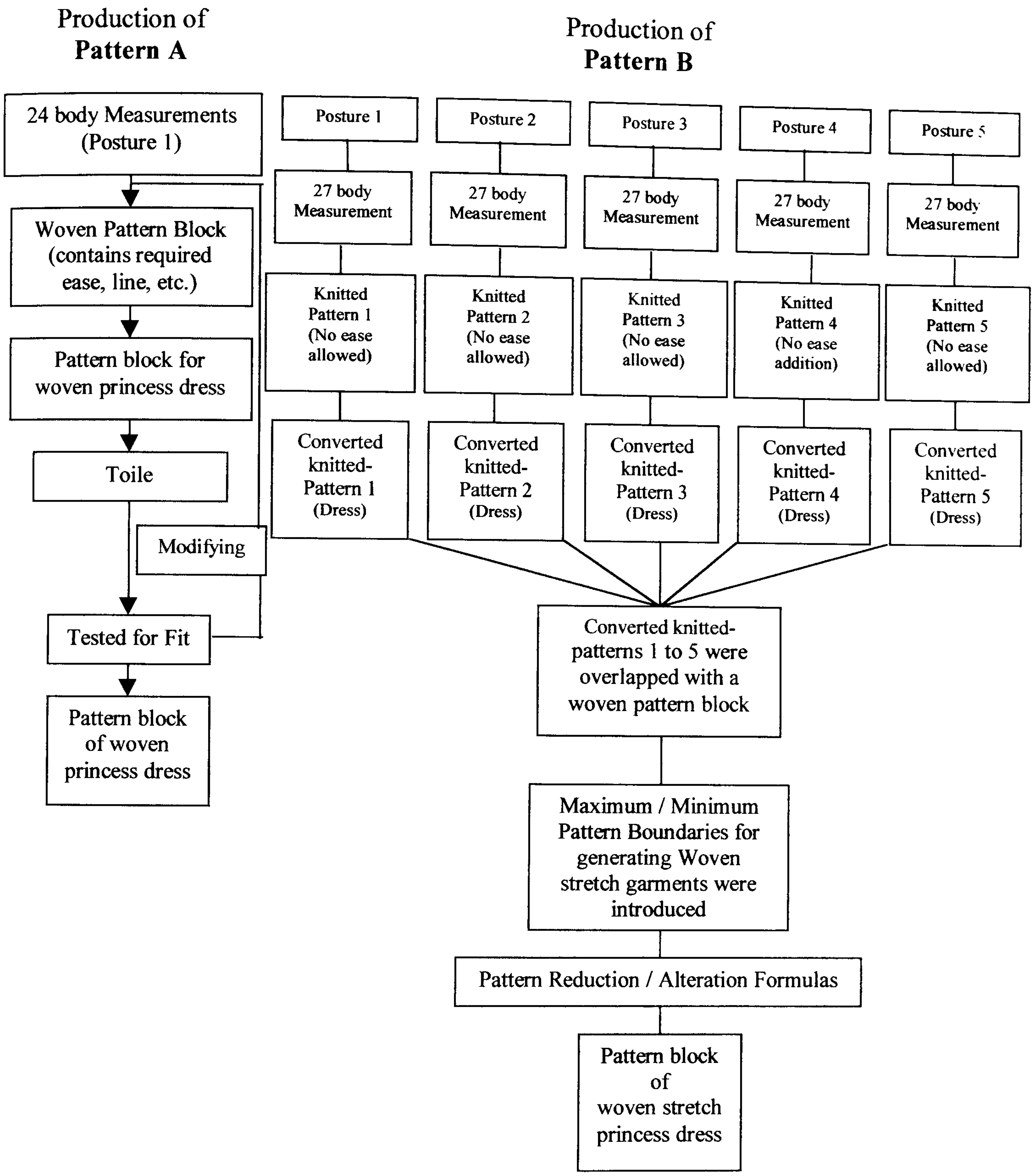


FIG. 5.7 Pattern producing processes of Pattern A and Pattern B illustrated and expressed in the chart. Pattern A was the pattern block of a woven princess line dress developed in Section 5.3. The developed knitted pattern blocks were presented in Section 5.4. Pattern B was the pattern block of a woven stretch princess-line dress presented in Section 5.5.

5.3 Pattern Construction of Tailored Woven Garments

5.3.1 Objective

There are three objectives in this section. They are (1) to draft a basic pattern block for a woven garment; (2) To generate a tailored pattern block for well fitted shoulder princess-line dress based on the woven pattern block; and (3) to complete the woven princess-line dress following the trial and error system to insure the accuracy. The presented woven princess-line dress was the specified dress form in the present work and was used as the reference for garment comparison. Hereupon the woven pattern block was further developed with knitted pattern blocks to help with generating the desired woven stretch pattern block.

5.3.2 Size Measurements

24 traditional body size measurements on the appointed model in the upright standing position were taken for constructing the basic pattern block for woven fabric. Table 5.1 shows the definition of these 24 body measurements and their measured sizes.

5.3.3 Pattern Construction and Modification of Woven Princess-line Dress

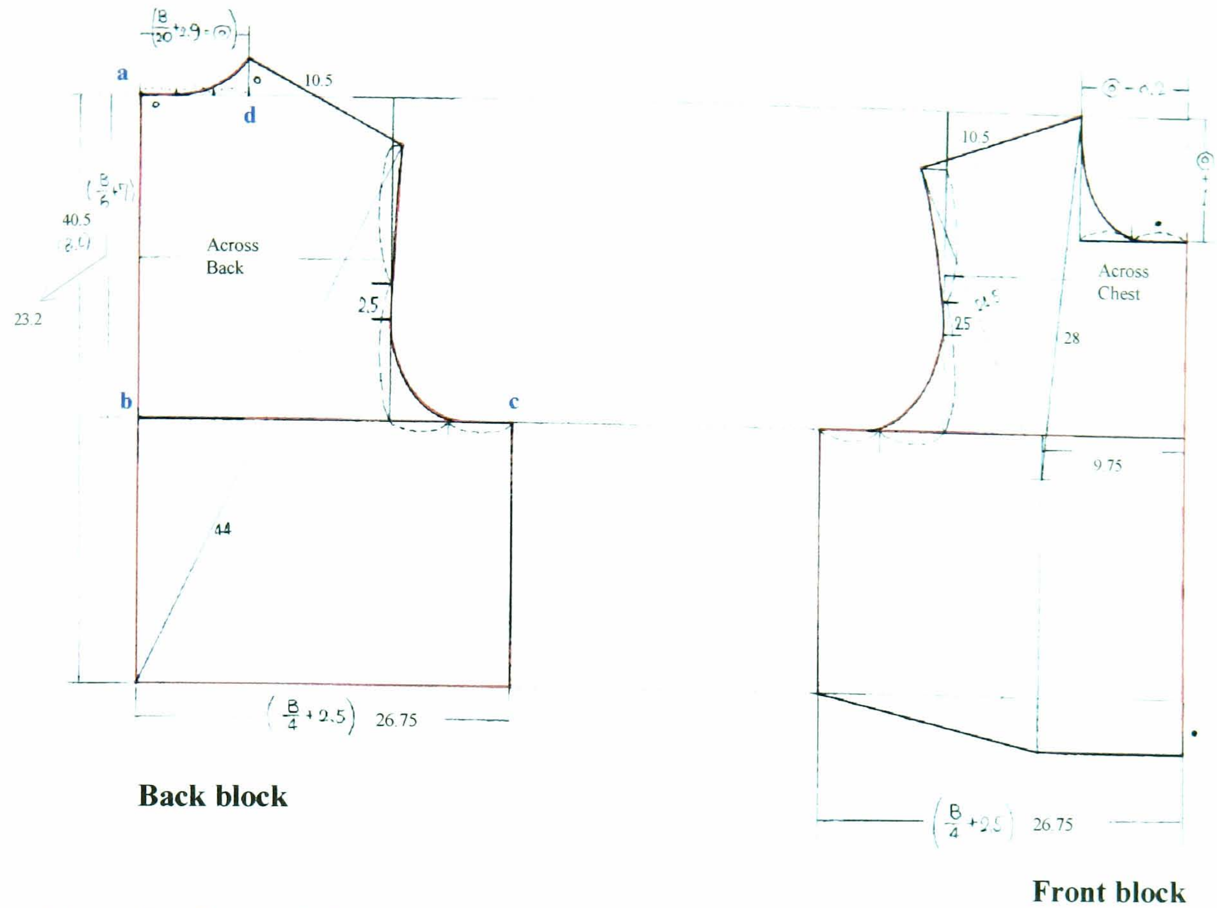
A basic pattern block of woven fabric was produced from the 24 body size measurements as described in Table 5.1. The methodology used to construct the flat basic pattern block in this study was according to two references: (1) Patternmaking for Fashion Design by Armstrong (1995) and (2) Clothing Construction Theory by Miyoshi (1985). The first reference of a pattern making method was to apply individual size

Table 5.1 The 24 body size measurements used to produce a basic pattern block of woven fabric

Body Size Measurement			
No	Position of Measurement	Definition	Model size (cm)
1	Bust	Across bust point and back	97.00
2	Waist	Across waist	79.00
3	Abdomen	Three inches below waist	96.50
4	Hip	Measure widest area with tape parallel with floor.	97.00
5	Centre front length	Neck to waist (over bust bridge)	38.00
6	Centre back length		40.50
7	Front full length	Waist to shoulder at neck, parallel with centre lines	44.50
8	Back full length		44.00
9	Bust depth	Shoulder tip to bust point	24.50
10	Back shoulder slope	Back centre of waist to shoulder tip	44.00
11	Shoulder length	Shoulder tip to neck	10.50
12	Full across back	Centre back to mid-armhole	16.75
13	Full across chest	Centre front to mid-armhole	15.50
14	Side hip depth	Side waist to hip, on side of form being measured	18.00
15	Bust point length	Side neck tip to bust point	28.00
16	Bust point distance	The distance between two bust points	9.75
17	Sleeve length	Shoulder tip to wrist point	54.00
18	Elbow length	Shoulder tip to elbow point	31.50
19	Skirt length	Side waist to knee	51.00
20	Upper arm	Measure widest area of upper arm with tape	31.00
21	Wrist girth	Around wrist point	28.00
22	Upper leg	Measure widest area of upper leg with tape	94.50
23	Neck	Around centre neck point to the side neck point and back neck point	40.00
24	Under bust	Around under bust	80.00

measurements with very little ease allowance to construct a personal basic pattern block specifically. The second reference of a pattern making method introduced well-confirmed pattern construction and formulas as the criterion to generate a formulated individual pattern block. This theory for pattern generation was the most currently used, especially for Asian females (the appointed model is an Asian female). Moreover, two pattern making methods worked faultlessly and conveniently most the time, as known from the experience of many pattern makers in Asian countries such as Japan and Taiwan.

Figure 5.8 shows the basic pattern block for the woven fabric. In Figure 5.8 shows the length of centre back (B.C) was 40.5cm in the back pattern block. According to the previous theories for pattern making, the length from back neck point to reach the point at the armhole line near the mid-length of the centre back length (a↔b), the quartered width of the pattern block (whole body girth) (b↔c) and the width of halved back neck (a↔d) were calculated from the bust girth (B). The calculation formulas (Miyoshi, 1985) are shown in Table 5.2. Hence the halved width of the front neck was obtained by subtracting 0.2cm from the width of the halved back neck. The depth of the front neckline was obtained by adding 1cm onto the width of halved back neck. The results are shown in Table 5.2 and Figure 5.8. Further, the curved dash line shown in the patterns were the half-and-half length (e.g. a mark expressed as "•" in the front pattern) or the equal length of the engaged distance (e.g. a mark expressed as "o" in the back pattern).



Note: B-- Bust girth

FIG. 5.8 The basic pattern block of woven fabric was constructed based on the 24 body size measurements.

Table 5.2 Pattern Construction

Line description	Formula for Calculation	Sizes (cm)
The length from back neck point to reach the point at the armhole line near the mid-length of the centre back length (a↔b)	(Bust girth ÷ 6) + 7	23.20
Quartered width of the pattern block (body trunk)	(Bust girth ÷ 4) + 2.5	26.75
Width of halved back neck (a↔d)	(Bust girth ÷ 20) + 2.9	7.75
The halved width of the front neck	width of halved back neck - 0.2	7.55
Depth of the front neckline	width of halved back neck + 1	8.75

Note: Bust girth (B) is 97cm (see Table 5.1)

A basic block normally has two darts in order to provide good fitting and a rounded effect over the bust points. These two darts are normally either at the waist and shoulder or the waist and underarm. These are the combinations that give the best fitting for a basic block. However, darts can be placed anywhere round the bust, but must always point towards the bust point (Mee and Purdy, 1987). The fitted princess-line dress was used for examining the pattern developments of the project. The pattern blocks of a "princess-line dress" of woven fabric were then achieved based on this basic pattern block. The princess-line dress is the panel bodice continued to full dress length, with more or less width at the hem, according to the style (Natalie, 1986). Details of making the patterns are illustrated in Figure 5.9 (the body block of the dress) and Figure 5.10 (the set in long-sleeve block of the dress). Minimum ease was added into the pattern of the woven princess-line dress and used to produce the most suitable fit and comfort without too loose or too tight. Darts of the woven princess-line dress were designed appropriately to accommodate bulges and shape changes of the front and back body trunk (e.g. bulged bust girth and slimmed waist girth). Shaped 3D princess-line dress give the possibility to alter flat patterns into a three-dimensional garment figure. The shaped princess-line dress also decreases the pattern dimension gradually through the waistband (slimmest girth) down to the increased dimension of hipbone (widest girth) then straight down to the hem. The required ease and difference in the front and back patterns were also considered and shown in the areas of waist girth (Waist Line) and hip girth (Hip Line) of the dress pattern. Their calculations are described below.

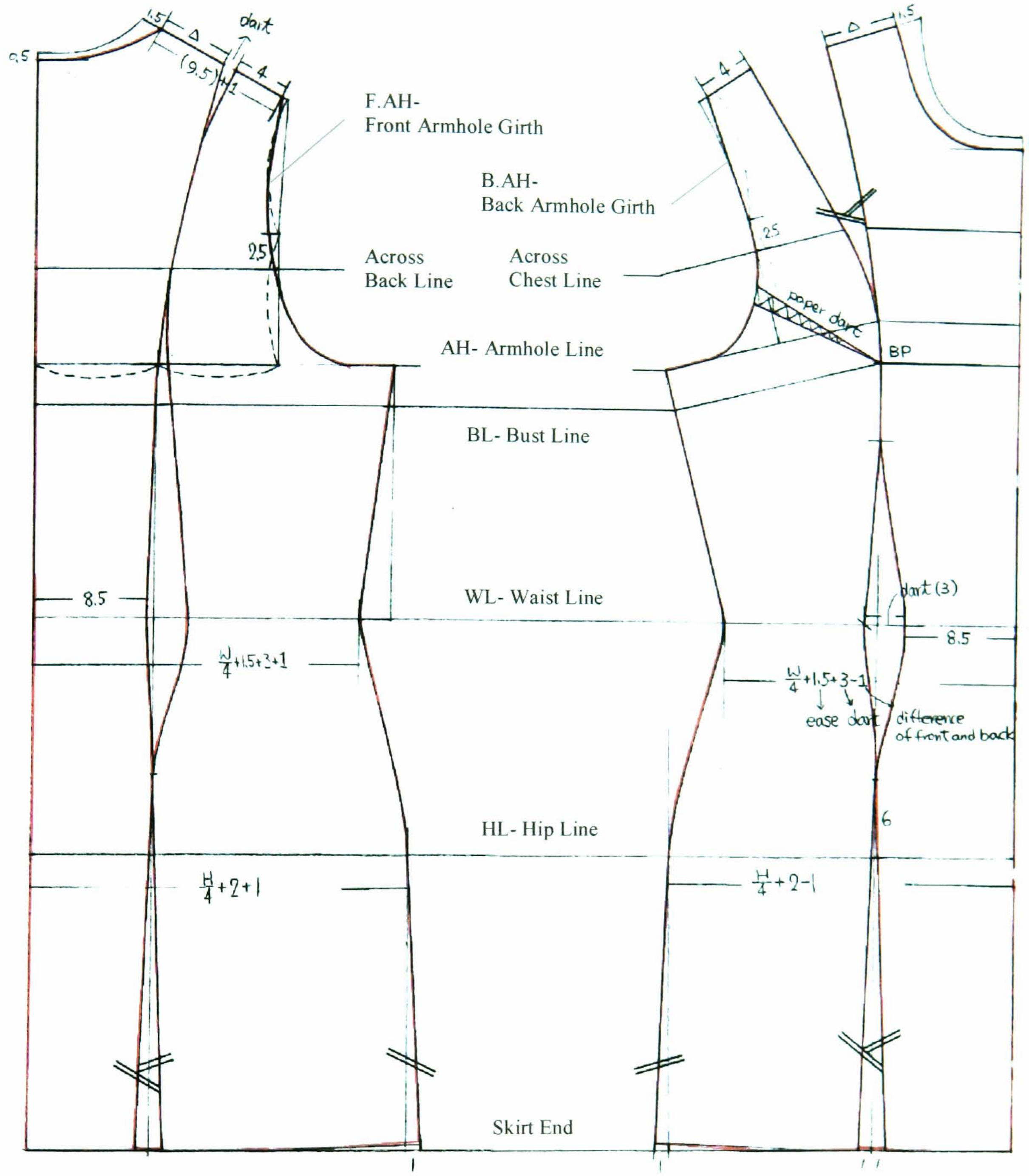


FIG. 5.9 Pattern blocks of woven princess-line dress based on basic block shown in Figure 5.8.

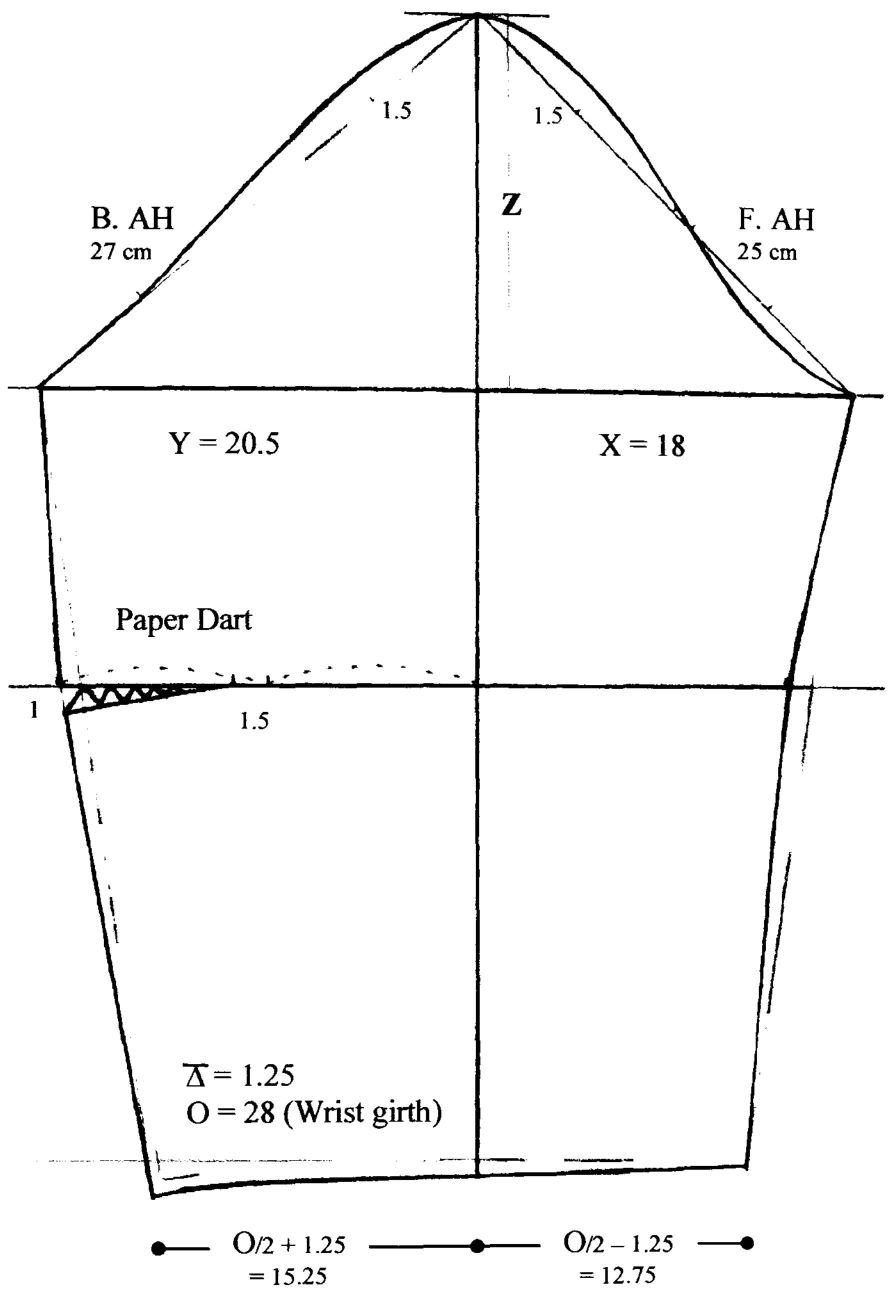


FIG. 5.10 Long-sleeve pattern block for woven fabric constructed for woven princess-line dress shown in Figure 5.9.

Pattern dimension of halved front pattern block at waist

Total amount of ease at waist girth = 1.5 cm (ease) + 3 cm (dart) – 1 cm (girth difference between body front part and back part at waist) = 3.5 cm

Therefore, pattern dimension of halved front pattern block at waist = one fourth of the waist girth (W/4) + 3.5 cm = 23.25 cm, because the waist girth is 79 cm (see Table 5.1).

Pattern dimension at hip

Total amount of ease at hip girth = 2 cm (ease) – 1 cm (girth difference between body front part and back part at hip) = 1 cm.

Therefore, the pattern dimension at hip = one fourth of the hip girth (H/4) + 1 cm = 25.25 cm, because the hip girth is 97 cm (see Table 5.1).

Pattern dimension of halved back pattern block at waist

Total amount of ease at waist girth = 1.5 cm (ease) + 3 cm (dart) + 1 cm (girth difference between body front part and back part at waist) = 5.5 cm

Therefore, pattern dimension of halved back pattern block at waist = one fourth of the waist girth (W/4) + 5.5 cm = 25.25 cm, because the waist girth is 79 cm (see Table 5.1).

Moreover the pattern design of the dress pattern block for the back body shape was based on the basic pattern block of woven fabric but with insertion of the shoulder princess line and shaping of the pattern dimension as the front pattern block.

Pattern dimension at hip

Total amount of ease at hip girth = 2 cm (ease) + 1 cm (girth difference between body front part and back part at waist) = 3 cm.

Therefore, the pattern dimension at hip = one fourth of the hip girth (W/4) + 3 cm = 27.25 cm, because the hip girth is 97 cm (see Table 5.1).

A paper dart in the front pattern block was constructed necessarily for the garment fit and has to be folded (due to the bulged bust) before the pattern was finalised for cutting. Figure 5.10 shows the basic long-sleeve pattern block for the shoulder princess-line dress. The sleeve pattern block was constructed based on the size of the front armhole girth (F.AH: 25cm) and back armhole girth (B.AH: 2cm) of the shoulder princess-line dress (see Figure 5.9), because Z = AH/4 + 2.5 (+ shoulder pad height) = (B.AH + F.AH)/4 + 2.5 (+ 1 ~ 1.5). Thereby the width of the back sleeve (Y) and the width of the front sleeve (X) were obtained from measurements. These were 20.5cm (Y) and 18cm (X), respectively as described in Figure 5.10. From the width of the back sleeve (Y) and the width of the front sleeve (X), the increase or decrease for the cuff width was

$[(Y + X) / 2] = 19.25$ cm, and

19.25 cm – X = 1.25 cm or Y – 19.25 cm = 1.25 cm

$\overline{\Delta} = 1.25$ cm

The total cuff girth (= wrist girth, see Table 5.1) measured was 28 cm = (O), therefore

(O) / 2 + 1.25 = 15.25 cm for the back cuff width (Y), and

(O) / 2 – 1.25 = 12.75 cm for the front cuff width (X)

A dart along the inside seam of the long-sleeve pattern block was constructed to give improved sleeve fit. The basic pattern block (see Figure 5.8) was manipulated into the woven princess-line dress (see Figure 5.9) as the base by following the traditional pattern cutting techniques. Further the woven princess-line dress was made into a calico garment called a toile (see Figure 11). The toile had to fit the appointed model. Therefore the toile was altered until it fitted the model. This process of the fitting and

a. Photo of the front **b.** Photo of the side **c.** Photo of the back

FIG. 5.11 Three photos show the appointed model during the trial and error procedural to fit the toile (woven princess-line dress) to confirm to fit and comfort correctly

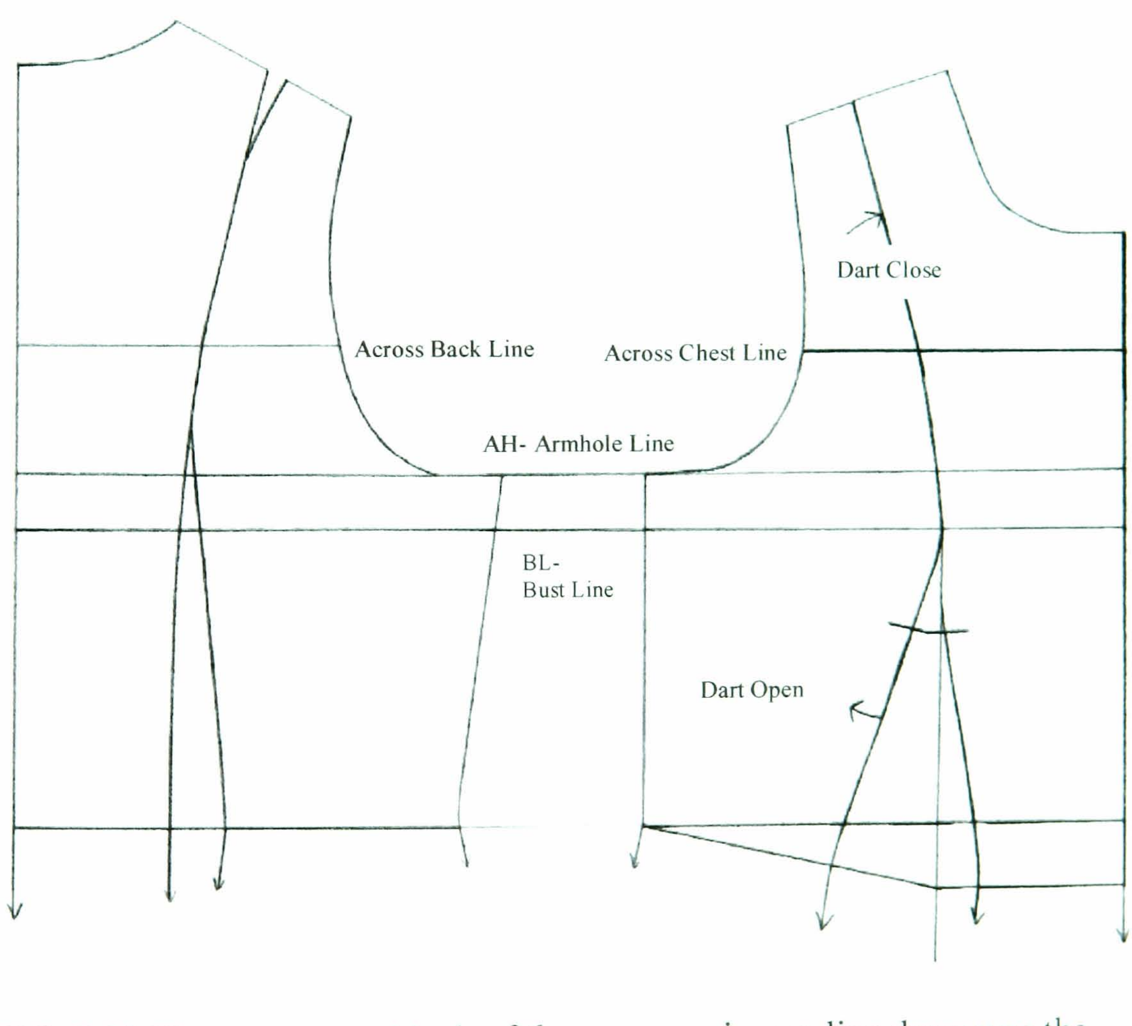


FIG. 5.12 The cut pattern block of the woven princess-line dress was the pattern form for all patterns in the project

refitting a toile is called “the trial and error system” and used for any alterations to the toile and re-cut patterns. Figure 5.11 shows the photos of the appointed model who wore the toile. The pattern block of the woven princess-line dress was altered and modified three times before the wearer and experienced judges were satisfied with the fit and comfort. In Figure 5.11 the dash lines stitched on the surface of the toile were the balance lines and girth lines. Figure 5.12 shows a pattern block cut from the waist girth (Waist Line) of the woven princess-line dress (see Figure 5.11). The pattern block dart was manipulated princess line into a style as shown in Figure 5.12.

5.4 Body Movement and Their Pattern Development

5.4.1 Objective

The objective was to introduce five postures of body movements to obtain the extended pattern sizes, and then to produce their extended pattern blocks for observation of garment distortions and changes. These five postures were to take the major extended body movements into account to bring the comfort requirements into pattern design. A body's dimension alter upon the posture changes. Pattern blocks of five posture changes were obtained from measuring the size on the surface of a skin-fit-knitted jersey garment while the appointed model was wearing the specified jersey garment and assuming the five postures. Hereupon, the pattern blocks based on the size changes of the five postures were presented and used in the development of the woven stretch patterns.

Two important steps were involved during pattern development. The first was to define five extended postures and the second was to measure the pattern sizes accurately by using objective measurement. In order to capture the changes of pattern size and variations of the five extended postures, a skin-fit-knitted jersey garment was selected. This employed the stretch and recovery properties of the fabric to accommodate the movement variations during the extreme posture positions.

5.4.2 Defining the Five Postures for Body Movements

Different functional postures used in anthropometric and ergonomic studies were found useful in this study (Miyoshi and Hirokawa, 1995 and Tilley, 1993). Five postures were used to simulate extreme body movements to help to produce a desired pattern block, which allows the body to move comfortably. Five major movements were selected and used to present body stretch as shown in Figure 5.13 and Table 5.3. A basic standing upright posture was appointed as the starting position. Five postures were started from a relaxed upright position to the extended positions through the midway to the maximum extensions and a stretched flexion position.

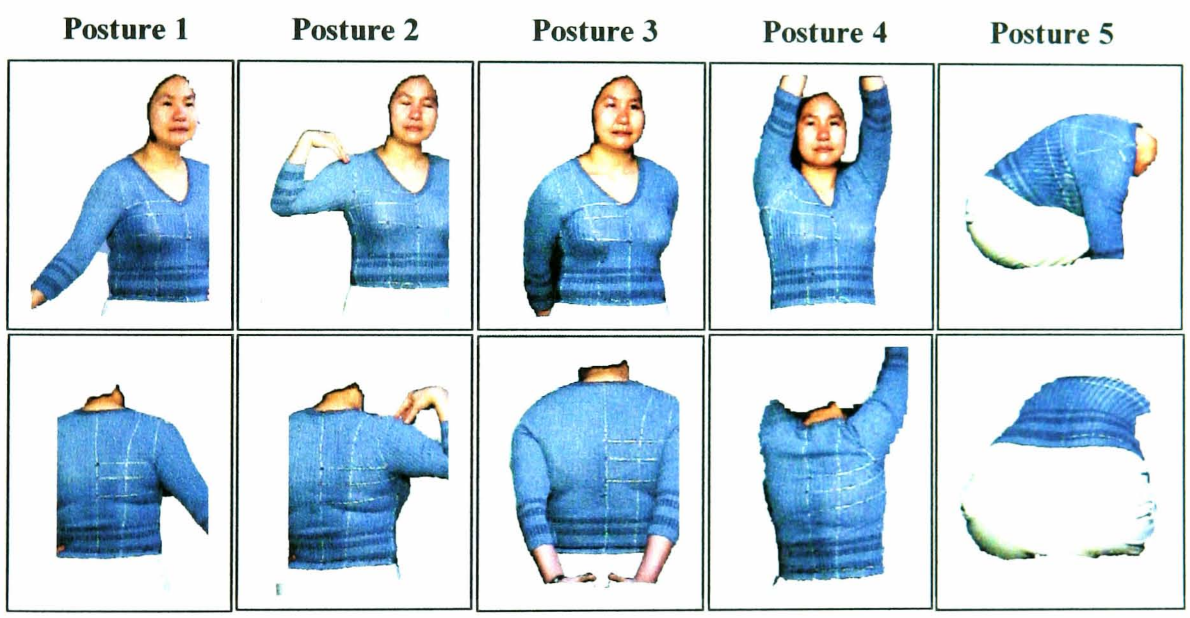


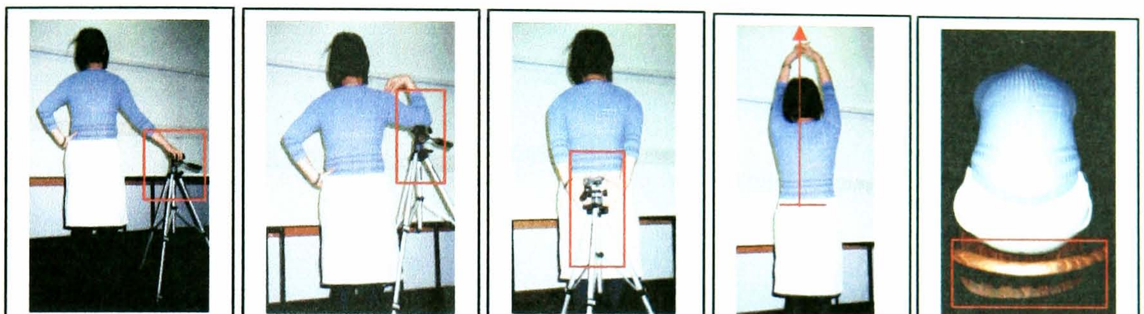
FIG. 5.13 Five postures were issued. The changes of size measurements were measured from the surface of skin-fit-knitted jersey garment while the appointed model was in five positions.

Table 5.3 Description of five postures and their Figures in reference number

Number	Posture Description	Figure Number
Posture 1	Both arms held away from the body at approximately 45° from the trunk	Fig. 5.13 and 5.14a
Posture 2	Both arms near 90° to the trunk + hand touching the tips of shoulder blades	Fig. 5.13 and 5.14b
Posture 3	Arms behind the back	Fig. 5.13 and 5.14c
Posture 4	Arms raised above the head with hand clasped	Fig. 5.13 and 5.14d
Posture 5	Crouching on a chair with the front of the trunk + touching the front ground by hand	Fig. 5.13 and 5.14e

From the observation of body movements it was seen that upper arms and lower arms had an important role to play in the garment distortions. The armpit points of the upper trunk were the main join points between the arms and upper trunk of the body. The range of different arm movements were investigated and discussed before the five postures were finally set.

Posture 1 expresses the minimal extension of the garment stretch. Posture 2 expresses two extended poses, the first was to extend the upper arm to achieve an arm posture near 90° and the second was to bend the lower arm to reach the shoulder tip. Both of them were planned to capture the midway extension. Deformation of posture 2 occurred mainly depending on the arm stretch and elbow stretch. Posture 3 expresses the extensions, which appeared across the chest area and bust area, and rotates the armhole area and shoulder area at the same time. Posture 4 expresses the extensions by raising the arms to reach a vertical tallness near 180°. Distortion occurred through the risen arms and shoulder areas to the whole body trunk. Posture 5 expresses the extension of back trunk area and the arm stretch, which was largely lengthening the length of the back trunk. In order to reproduce the range of the five postures a standard tripod and a chair were appointed and used to engage and fix the positions as shown in Figure 5.14. This ensured that measured results were reproducible and repeatable. Figure 5.14a, 5.14b and 5.14c show the method to adjust postures 1, 2 and 3. Posture 4 keeps the position by raising the arms to reach a vertical tallness near 180° shown in Figure 5.14d. Posture 5 shows the position by locating the body to sit upon an appointed chair as shown in Figure 5.14e. Pattern development for accommodating the body movement was investigated. The five extended pattern sizes and their pattern blocks of the specified jersey garment will be presented later.



a. Posture 1 **b.** Posture 2 **c.** Posture 3 **d.** Posture 4 **e.** Posture 5

FIG. 5.14 The illustrations show the procedural of posture adjustment from posture 1 to posture 5. Postures 1, 2 and 3 have been adjusted by use of the fixed calibration individually. Besides all postures can be reproduced and repeated surely by adjusted method presented in here.

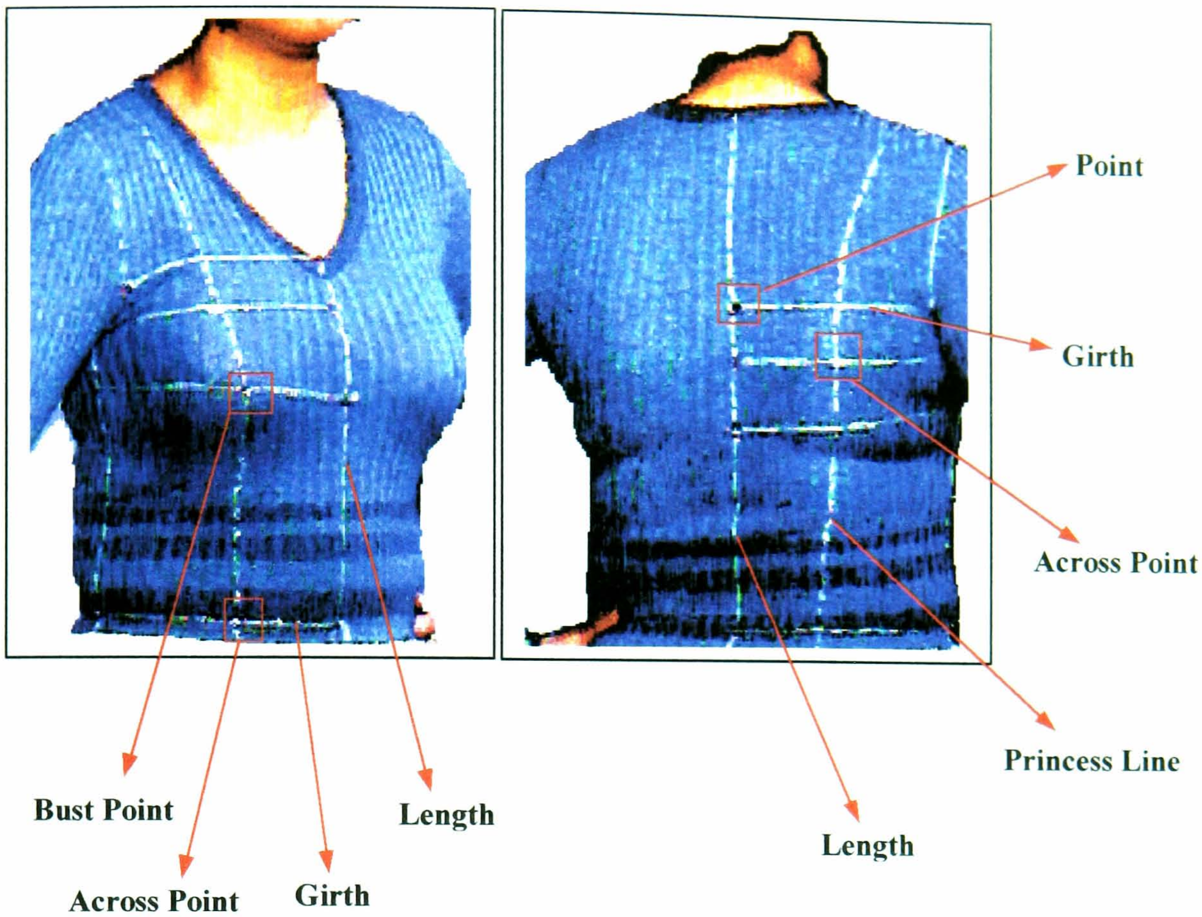
5.4.3 Size Measurements

In practice, size measurements for woven garment design are usually taken on a lightly clad human body in a standing upright posture and carried out without taking into account the garment slippage which occurs while wearing the clothes. This is the usual method to measure a body size as used by human engineers, anthropometric experts, human dynamic scientists and pattern designers. Much of the garment restriction on body movement was released by the amount of garment slippage.

Obviously stretch in a garment aids comfort because, for a given fabric extension, fabric tension is lower and body pressure lower. Therefore, the amount of slip between the fabric of garment and the skin surface was different between the woven garment and the woven stretch garment. However, this method is deficient to adapt the modern requirements of garment fit and comfort for woven stretch garments. An important factor should not be ignored, namely, that clothing is almost always part of the wearer when he/she is in a functional posture. In addition, the body movement is also affected significantly by clothing. For example, the maximum arm reach with free movement of the shoulder or trunk is much greater than with the shoulder and trunk restrained by clothing. Garment patterns must compromise with fabric properties, fit requirements and comfort requirements in both objective and subjective conditions. The observation also appears that body movements of one body segment are affected by the position or movements of the remaining parts of the body. Many body movements involve co-ordinated activity of several joints. The observed movements and body postures in a real activity context are much more complicated than that of anthropometric and ergonomic studies. For example, a movement of an arm forward reach could be extended by extending the shoulder, bending the trunk, or rotating the arm or trunk. These extreme movements and extended postures have to be taken into account in the pattern design.

In order to measure five extended pattern sizes the required marks and lines were given, as shown in Figure 5.15. The given points and lines were used to locate body girths and positions, crossed and jointed points, etc, and were marked on the jersey garment. Based on the pointed lines and points, 27 body measurements were defined.

• The Locations of Girth, Length and Point (Tip)



Thread was extended beyond the stitching line to allow for expansion. So it did not restrict the stretch of the garment.

• *Point:* Small buckles were sewn onto the garment surface and named as the point (e.g. Bust point).

• *Crossed Point:* The across marks was pointed out by applying a cross-stitch mark was applied.

• *Girth:* The girth stitches were located and fixed by sewing thread accurately onto the specified jersey garment (e.g. Waist girth).

• *Length:* The length stitches were located and provided by sewing accurately onto the specified jersey garment (e.g. Centre front / back length).

FIG. 5.15 Preparation on marking points, girths and lengths onto the garment surface to allow measuring the size measurement while it was being worn by the appointed model.

In order to measure five extended pattern sizes the required marks and lines were given, as shown in Figure 5.15. The given points and lines were used to locate body girths and positions, crossed and jointed points, etc, and were marked on the jersey garment, as shown in Figure 5.15. Based on the appointed lines and points, 27 body measurements were defined and given a reference number, as illustrated and described in Figure 5.16 and Table 5.4. Based upon the size measurements measured from the jersey garment, therefore, five knitted pattern blocks were obtained. In order to obtain an accurate pattern size from the extended five postures two measuring methods were used. First was the manual tape measurement method and second was a computerised three-dimensional body scanning and measurement. Therefore 27 size measurements of each extended pattern were obtained by measuring the required lengths and girths, distances, etc. from the given points and lines. All measurements were measured and confirmed three times each repeatedly and recorded in Table 5.5.

• 27 Body marks with the reference numbers: for the specified jersey garment

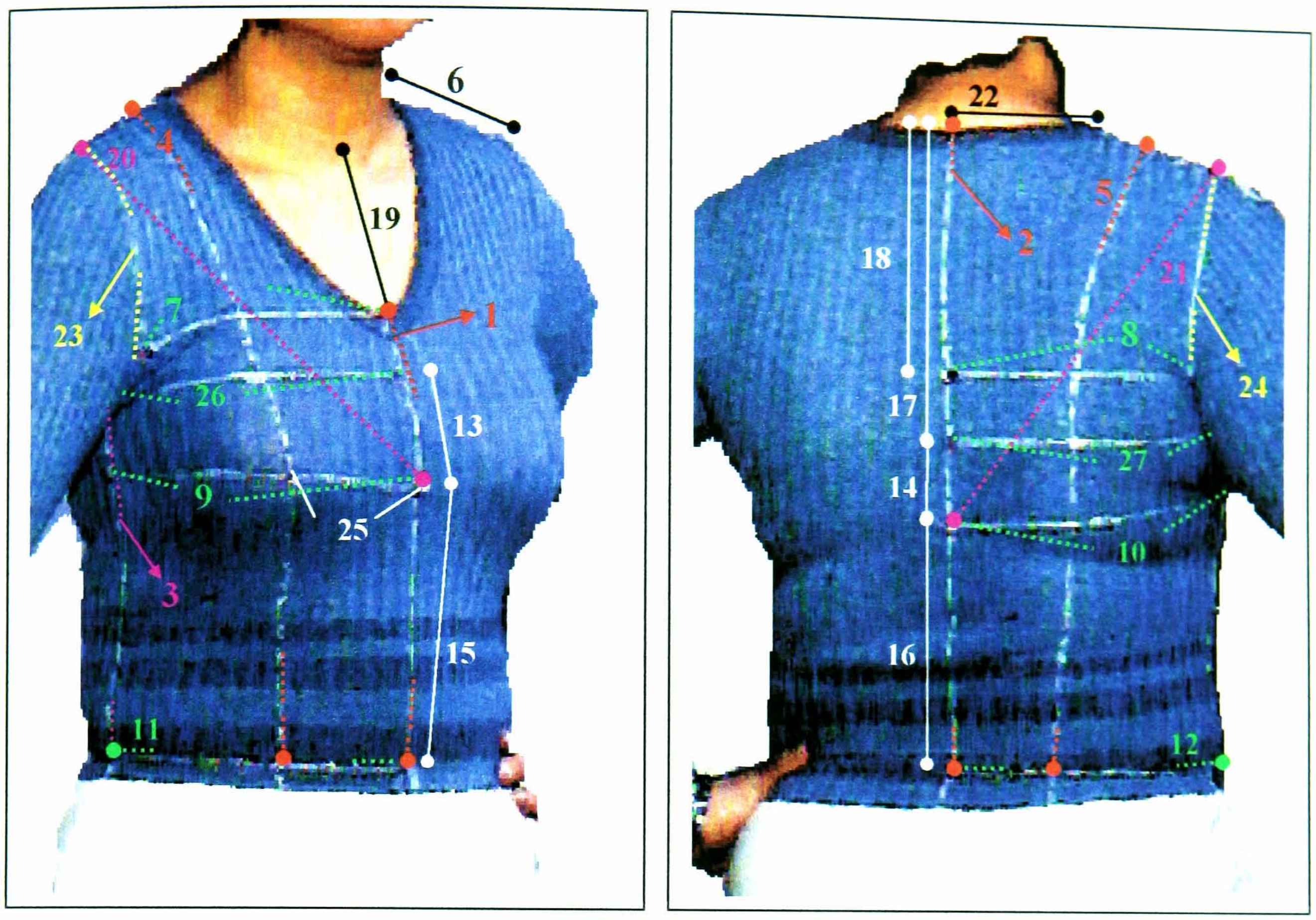


FIG. 5.16 The 27 body marks and their references for obtaining accurate body size

• Definition of the 27 Body Size Measurements:

Table 5.4 Reference numbers and definitions

Reference Numbers of Size Measurement	
1. Centre Front Length (= F.C)	**15**. Front Bust Line to Waist Line
2. Centre Back Length (= B.C)	**16**. Back Bust Line to Waist Line
3. Body Side	**17**. Back Neck Point to Across Back Line Point
4. Princess Line (Front)	**18**. Back Neck Point to Armhole Line point
5. Princess Line (Back)	**19**. Front Neck Point to Armhole Line point
6. Shoulder Length	**20**. Shoulder Point to Front Bust Line point
7. Full Across Chest	**21**. Shoulder Point to Back Bust Line point
8. Full Across Back	**22**. Neck Width (1/2)
9. Front Bust Line (= F-BL)	**23**. Front Armhole Girth (F-AH)
10. Back Bust Line (= B-BL)	**24**. Back Armhole Girth (B-AH)
11. Front Waist Line (= F-WL)	**25**. 1/2 Bust Point Depth (BP = Bust Point)
12. Back Waist Line (= B-WL)	**26**. Front Armhole Line (AH = Armhole)
13. Across Chest Line to Bust Line	**27**. Back Armhole Line (AH = Armhole)
14. Across Back Line to Bust Line	

Table 5.5 Size measurement from reference numbers 1–27 of body marks through posture 1 to posture 5

Number	Posture 1 hand	Posture 1 Computer	Posture 2 hand	Posture 2 Computer	Posture 3 hand	Posture 3 Computer	Posture 4 hand	Posture 4 Computer	Posture 5 hand	Posture 5 Computer
1	27.3	27.25	28.0	28.17	27.5	27.27	27.5	27.46	•	•
2	40.5	39.94	40.5	38.86	42.0	41.75	37.0	37.17	45.5	•
3	24.5	24.16	26.0	26.04	23.8	22.77	27.5	27.51	24.0	•
4	47.0	46.58	47.0	46.86	45.6	45.51	47.3	•	•	•
5	43.0	41.52	43.0	42.47	43.7	42.91	41.5	•	47.5	•
6	9.0	9.04	6.8	6.85	9.0	9.02	5.0	•	7.7	•
7	17.5	17.81	17.5	17.61	17.3	•	14.5	14.55	•	•
8	18.5	•	21.0	18.09	15.8	•	20.5	20.15	22.3	•
9	24.5	24.32	24.5	24.53	25.5	25.43	23.3	23.37	•	•
10	22.8	22.7	23.0	22.75	21.5	•	23.5	23.51	24.0	•
11	20.0	20.15	20.0	19.99	21.0	20.56	19.3	19.24	•	•
12	21.0	20.13	21.0	20.89	21.0	•	20.2	20.11	20.5	•
13	10.8	10.79	11.5	11.49	11.0	11.15	11.0	11.02	•	•
14	8.8	8.96	8.8	8.73	9.5	9.47	8.3	8.38	9.3	•
15	16.5	16.46	16.5	16.44	16.5	16.49	16.5	16.42	•	•
16	16.5	16.01	16.5	16.21	17.0	16.97	15.5	15.38	20.7	•
17	15.2	15.16	15.2	15.03	15.5	15.24	13.2	13.19	15.5	•
18	19.0	19.03	19.0	19.01	20.0	19.98	17.0	16.79	19.5	•
19	4.2.0	4.15	4.5	4.51	4.5	4.8	4.5	4.32	•	•
20	31.5	31.54	31.5	30.76	30.6	30.52	31.0	•	•	•
21	30.2	29.8	29.0	28.98	30.5	30.61	26.5	•	32.6	•
22	9.0	8.86	8.0	7.96	9.0	8.89	5.0	•	6.0	•
23	24.3	•	22.5	•	27.0	•	23.5	•	•	•
24	22.8	•	21.0	•	25.3	•	21.5	•	•	•
25	10.0	9.99	10.0	9.96	10.5	10.47	9.5	9.49	•	•
26	23.8	•	23.8	23.82	26.0	•	21.0	20.32	•	•
27	23.5	•	25.5	25.43	20.5	•	26.0	25.96	28.2	•

5.4.4 Size Comparison between Computerised Measurement and Manual Measurement

Traditionally, to make an optimum pattern, pattern makers gather anthropometric information of selected people by careful size measurement and draft specific flat patterns based on accumulated knowledge and experience. In the traditional manual pattern construction method, size measurement has been a fundamental but very important step that required considerable time and skill for a patterner to make accurate patterns (Ingham, 1983). This study used an easy and accurate method of gathering the necessary anthropometric size data for the pattern design. The method utilised three-dimensional measurement of the human body in comparison with traditional tape measuring. In order to make this process more precise and faster, auto-scanning equipment was applied (see chapter 3) to capture the necessary anthropometric size data from an appointed model. In Table 5.5 the dark dot " • " expresses the default size measurements measured unsuccessfully by the computerised measuring method. The percentage size difference between manual and computerised measurements was calculated as:

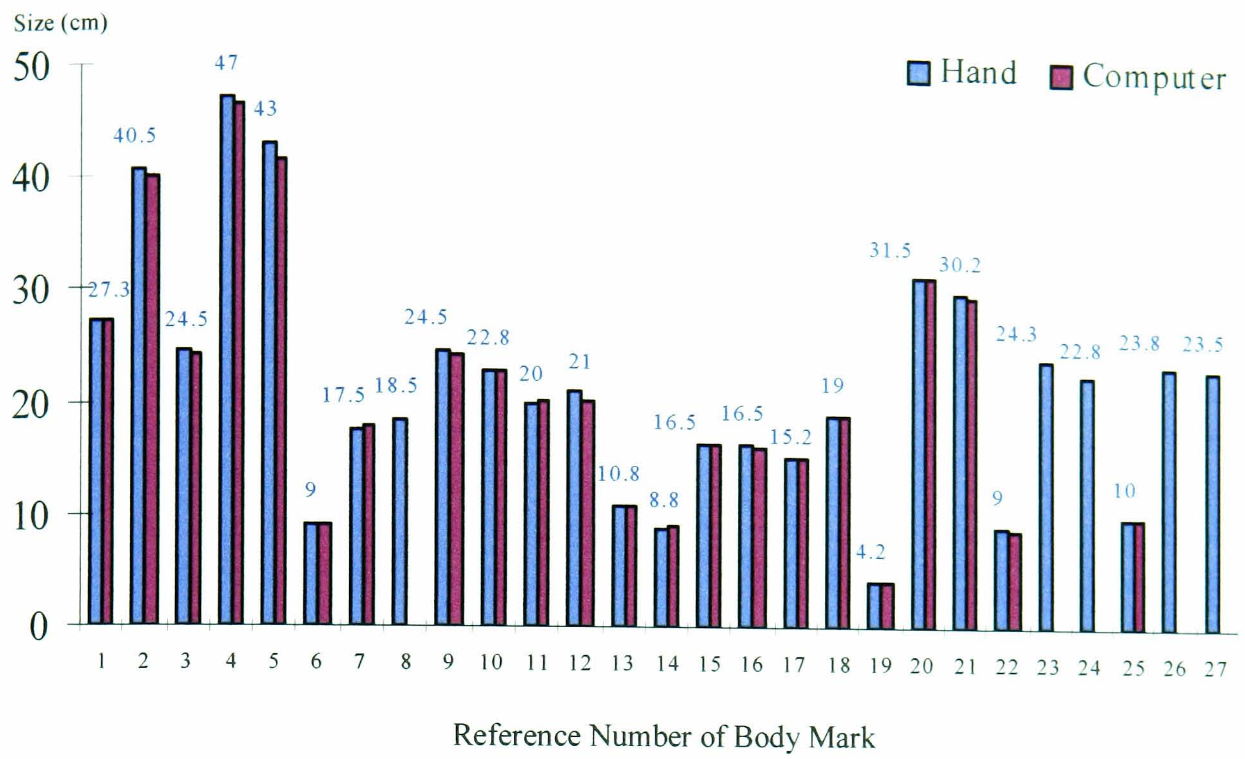
Percentage size difference $= 100\,(M_2 - M_1) / M_1$

Where: M_1 is the Size measured by the computerised 3D body scanner

M_2 is the Size measured by hand

The percentage size differences on reference numbers 1 to 27 under different postures were calculated for the evaluation of accuracy of 3D body scanner measurements. Figure 5.17 shows all the size measurements of upright standing posture (posture 1) by hand and scanner / computer, and their difference. It was found that the difference of size measurements between two methods was very small. But the

Size Measurement at Posture 1



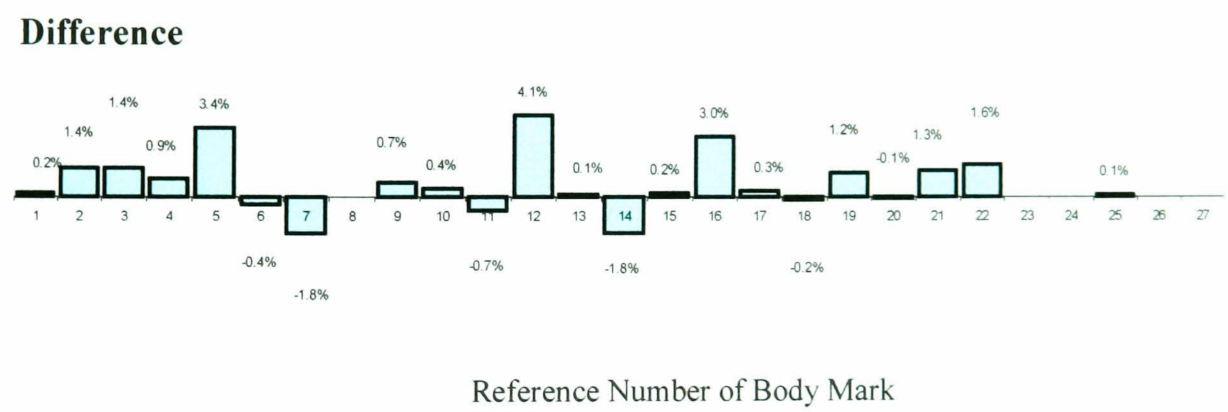
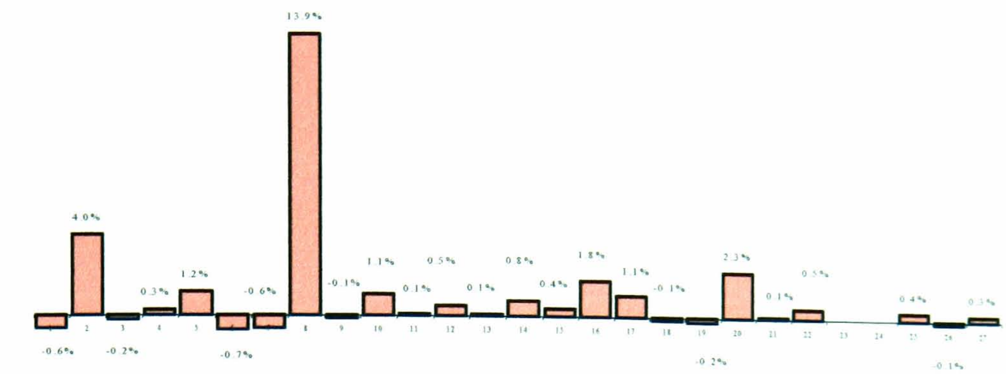


FIG. 5.17 All size measurements and their data of percentage difference from size measurements 1-27 at posture 1 were carried out. --Data provided by hand (■) and provided by computer (■)

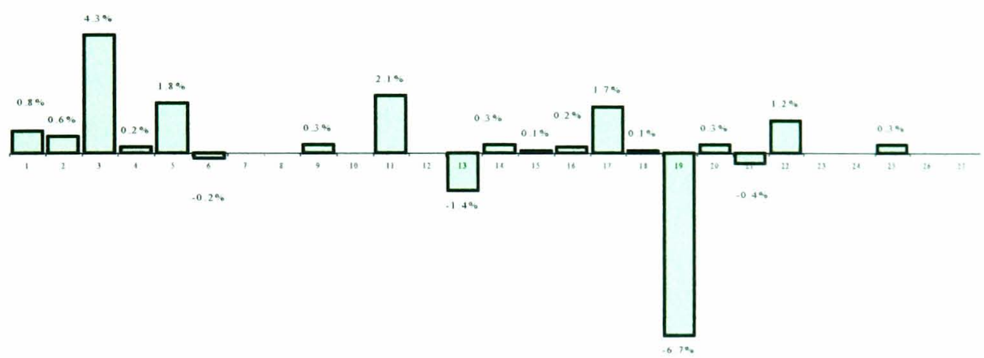
difference slightly increased for the extended postures (2 to 4) as shown in Figure 5.18. The maximum percentage difference was 0.14% which appeared in Posture 2 at the size measurement of full across back. It is also noticed that the 3D Body scanner was not able to detect some hidden body sizes at the bending postures.

Percentage Difference for Posture 2



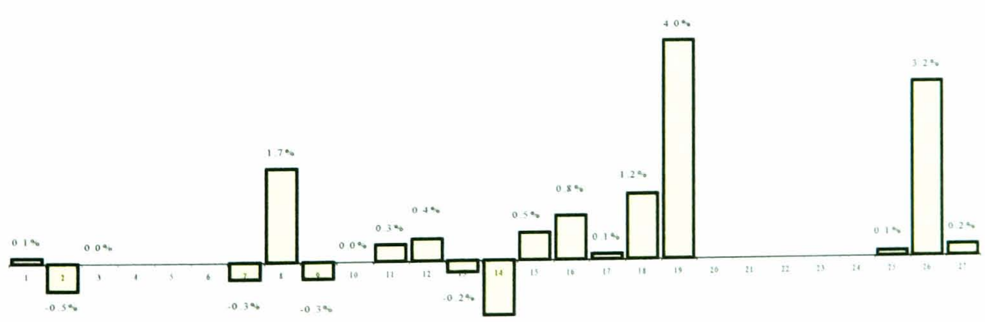
Reference Number of Body Mark

Percentage Difference for Posture 3



Reference Number of Body Mark

Percentage Difference for Posture 4



Reference Number of Body Mark

FIG. 5.18 Data of percentage difference at postures 2 and 3, 4 illustrated above

5.4.5 Effect of Body Movement on Garment Stretch and Fabric Distortion

The measurements of 27 marks on the jersey garment, worn by the appointed model, were carried out on the five defined postures. The results from the manual and the computerised measurements are shown in Table 5.5.

Posture 1 is the relaxed standing upright position without significant stretch on the body. The size from this basic anthropometric posture was used as reference for comparison to the size from the other stretched postures. The percentage increases in size between the postures were calculated as below.

$$\text{Percentage Increase in Size (\%)} = \frac{(\text{Size in Posture 1 - Size in other Postures}) \times 100}{\text{Size in Posture 1}}$$

The calculated percentage increase will show the stretch degree in different body area and give the relevant information of fabric distortion possibly occurred during the body movement. Figure 5.19 shows the percentage increase in size of Posture 2 to Posture 1. The size increases appeared at Body Side, Across Chest Line to Bust Line, Front Neck point to Front Armhole Line point, and Back Armhole Line (see Figure 5.16). It can be seen that the full across back and back armhole line are significantly stretched. The underarm area including body-side and armhole is also affected in extension. On the other hand the size decrease were found at four size marks including Shoulder Length, Neck Width, Front Armhole Girth and Back Armhole Girth. Actually it can be seen that the appeared decreases in size might be due to squeezing or creasing of the fabric in the area. In this project, the size decrease during the movement was not considered for the pattern reduction and alteration. In Posture 3 the size increases occur at nine size marks

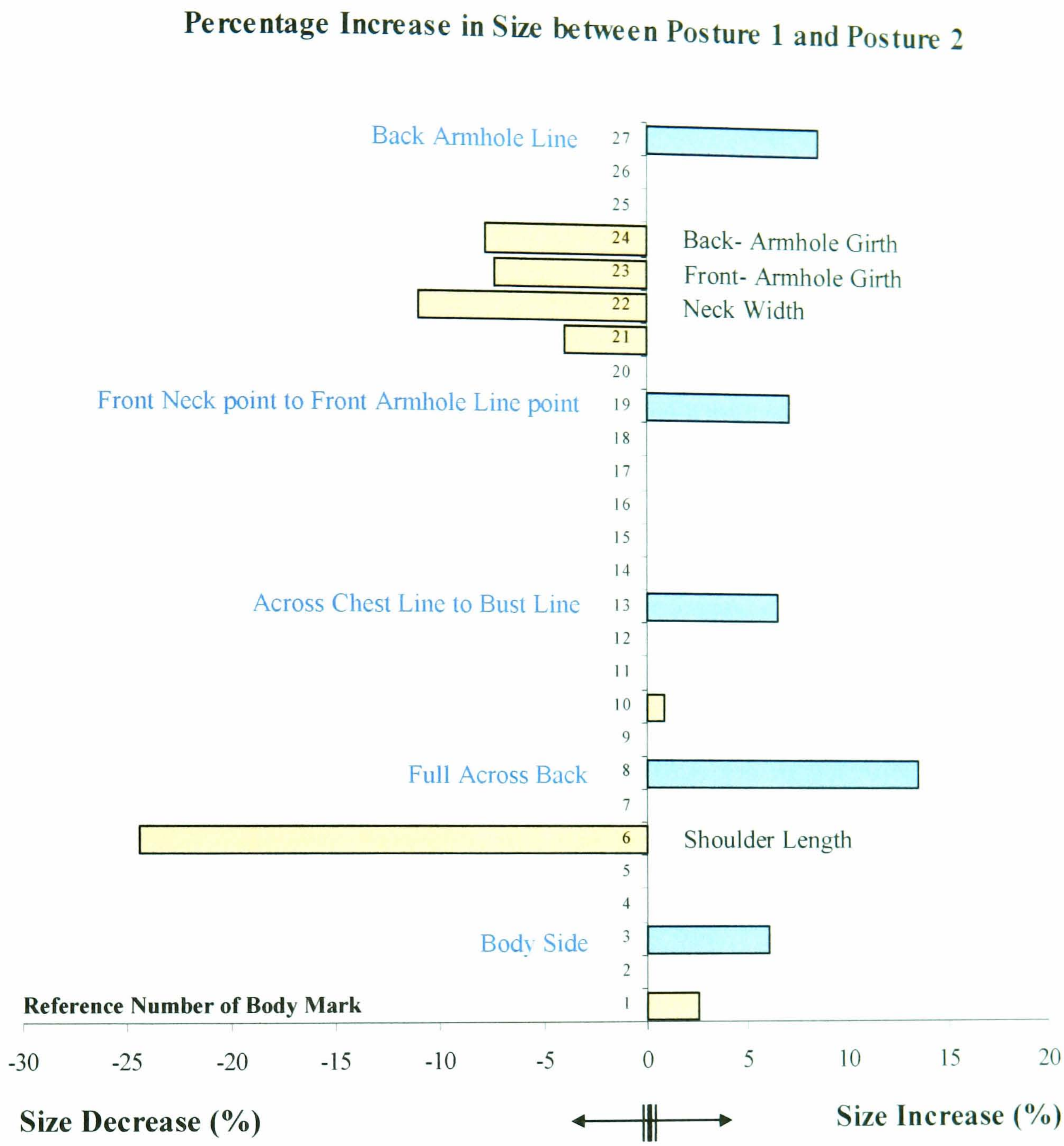


FIG. 5.19 Diagram for percentage difference of the 27 size measurements between Posture 1 and Posture 2. The anthropometric size data (%) of Posture 1 differs from Posture 2 due to the posture change that causes the extended or compressed areas of body surface to be different between each other.

as shown in Fig 5.20. Sixteen lines of 27 marks including Front Bust Line, Front Waist Line, Across Back Line to Bust Line, Back Neck point to Back Armhole Line point were stretched to a different extent. It shows that most parts of the body were stretched under Posture 3. The highest increases in size are Back and Front Armhole Girths about 10% around the armhole area. Because the size is measured on the marks of Jersey garment, which the model was wearing, the calculated value of size increase actually is reduced by garment slippage. The degree of stretch of body skin was higher than that of the jersey garment.

In Figure 5.21, it was found that only three lines significantly stretched by more than 10%. These were Back Armhole Line, Full Across Back and Body Side. The major stretches occur at the full back and body side due to the raising up of the arms. But most of the areas were compressed as shown in the reduction of their size. An intense increase in size for posture 5 was found, as shown in Figure 5.22. The biggest increases in size appeared at Centre Back Length, Full Across Back, Back Bust Line to Waist Line and Back Armhole Line, showing approximately 20% increase. It was shown that the whole area of the body back was significantly stretched, due to bending of the body trunk to allow the hands to reach the ground (see Figures 5.13 and 5.14).

From Posture 1 to Posture 5, the results show that the armpit area of a garment was most affected by stretching. This will be a very important consideration in the pattern construction and alteration for woven stretch garments. The size mark at Front Neck point to Front Armhole Line point, Full Across Back and Back Armhole Line increased in most of these five postures. Hence the larger size increase of the vertical

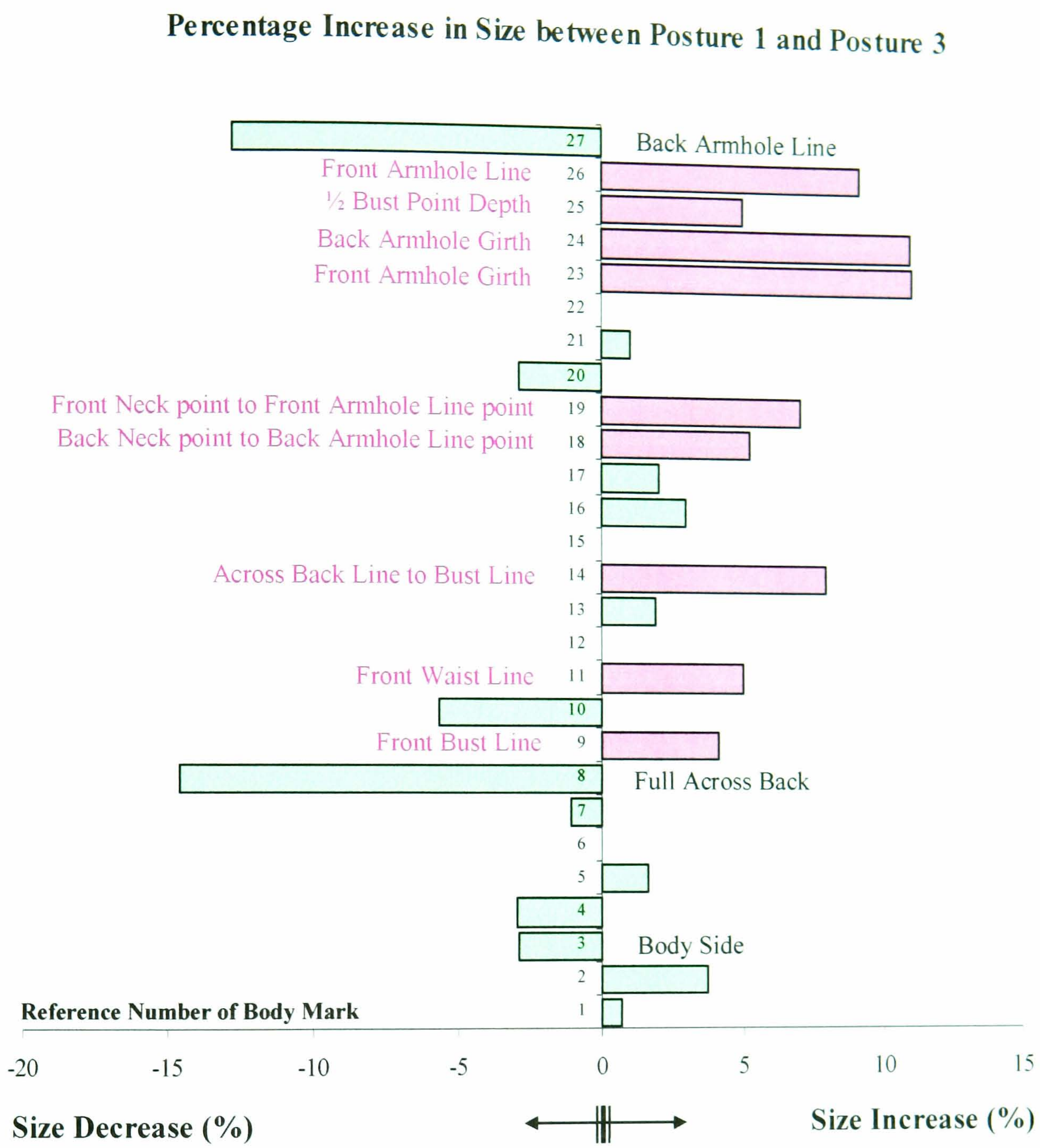


FIG. 5.20 Diagram for percentage difference of the 27 size measurements between Posture 1 and Posture 3. The anthropometric size data (%) of Posture 1 differs from Posture 3 due to the posture change that causes the extended or compressed areas of body surface to be different between each other.

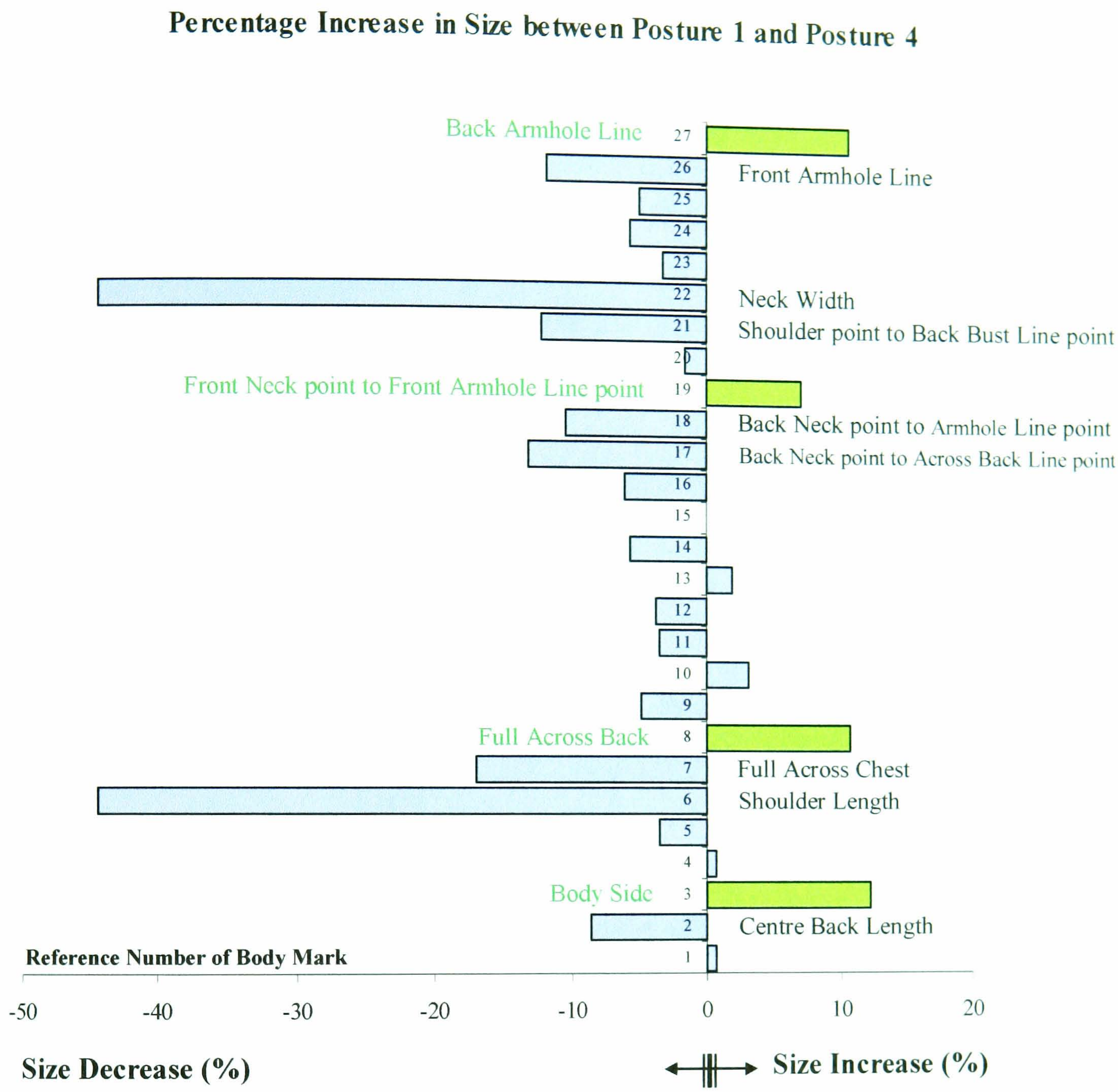


FIG. 5.21 Diagram for percentage difference of the 27 size measurements between Posture 1 and Posture 4. The anthropometric size data (%) of Posture 1 differs from Posture 4 due to the posture change that causes the extended or compressed areas of body surface to be different between each other.

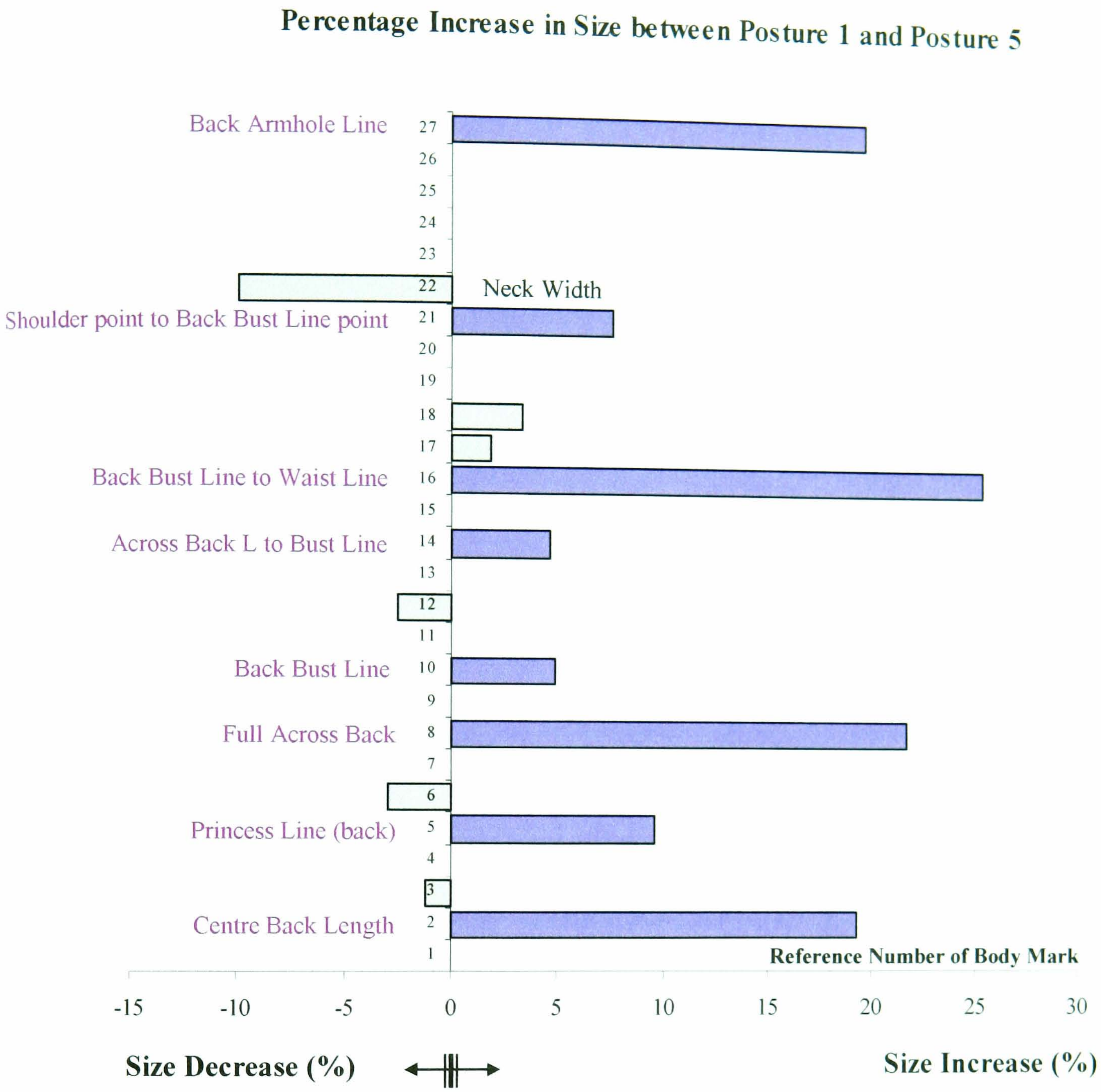


FIG. 5.22 Diagram for percentage difference of the 27 size measurements between Posture 1 and Posture 5. The anthropometric size data (%) of Posture 1 differs from Posture 5 due to the posture change that causes the extended or compressed areas of body surface to be different between each other.

direction was shown from the front neck point to the front armhole point. This is an important issue for generating the pattern construction of woven stretch garments especially when the pattern block was reduced in the horizontal direction while the length of the pattern block has to be extended in the vertical direction appropriately. Therefore the front neck point to the front armhole point should be the place to lengthen more than the other segments especially when a pattern is reduced.

5.4.6 Construction of Pattern Blocks from the Skin-fit-knitted Jersey Garment during the Body Movement

5.4.6.1 Objective

The main objective here was to utilise the five skin-fit-pattern sizes obtained using the jersey garment to generate five knitted pattern blocks.

5.4.6.2 Pattern Drafting and Construction for Skin-fit-knitted Jersey Garment under Individual Five Postures

A British standard mannequin of size 12 was to present the pattern form for this study. Figure 5.23 shows the pattern form used to locate size measurements. 27 size measurements from posture 1 (Table 5.5) were input into the pattern form. A pattern block of the jersey garment for posture 1 was drafted as shown in Figure 5.24. As well as the 27 size measurements, four extra size measurements were required to adjust the drafted pattern blocks into an accurate pattern construction. These four adjusted size measurements were expressed below, and the pink lines show their positions where the sizes were located (see Figure 5.24).

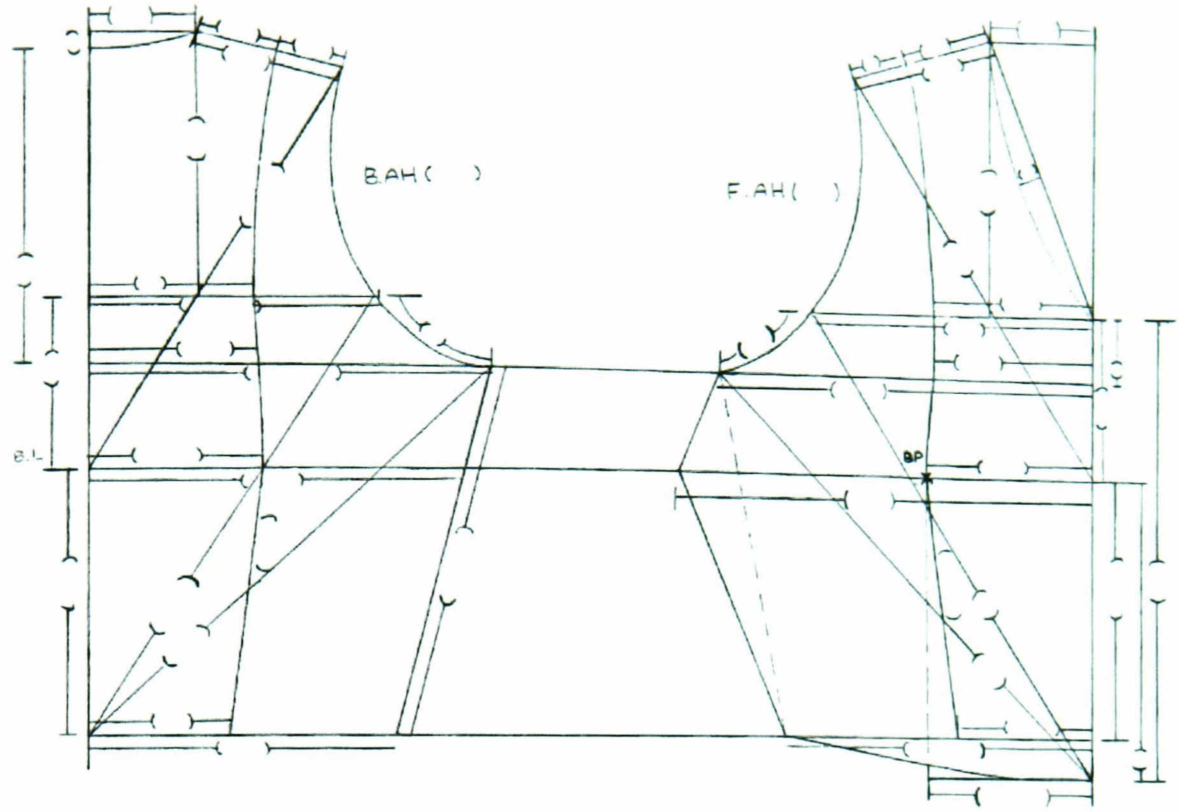


FIG. 5.23 Pattern form for size location by utilising BS: Size 12 mannequin

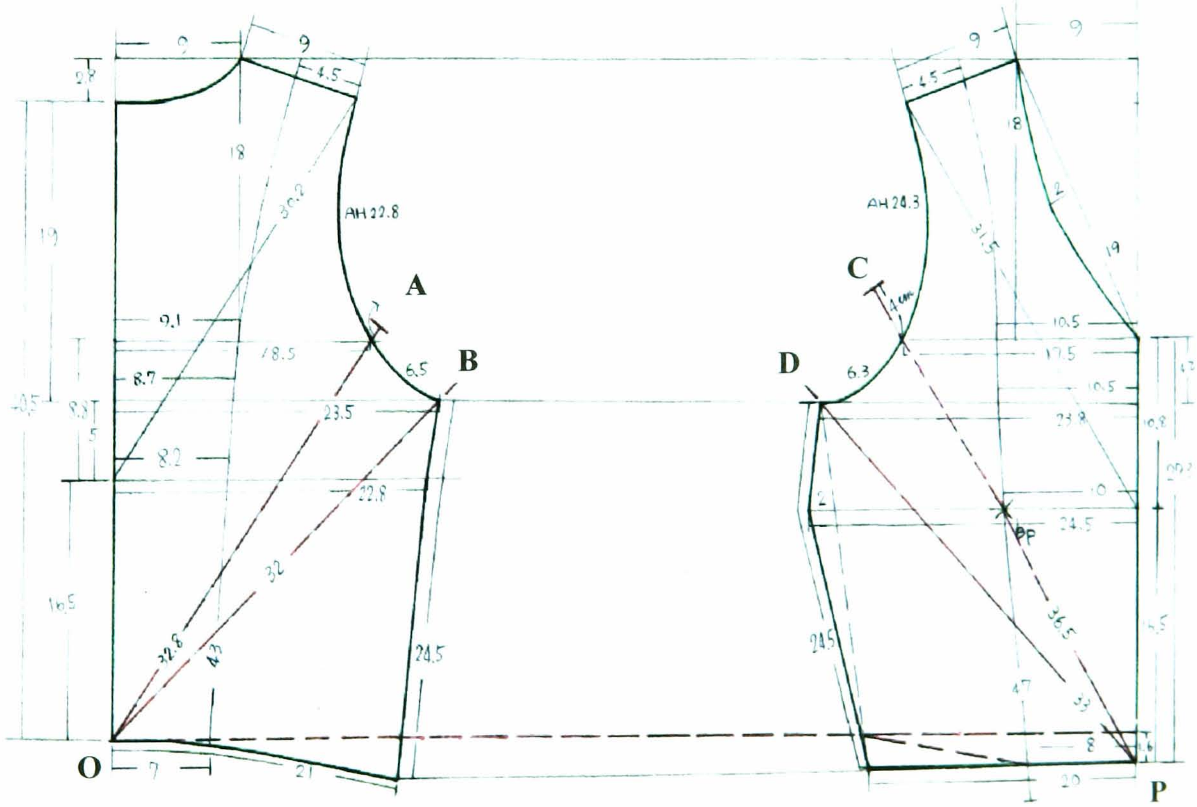


FIG. 5.24 This is the initial drafted pattern block of knitted jersey garment for posture 1. The 27 size measurements and four adjusted size measurements are expressed in this diagram.

(1). The first size measurement was defined from the corner point P of Centre Front Line to the edge point C of Across Chest Line upon the armhole girth named PC Line.

(2). The second size measurement was defined from the corner point P of Centre Front Line to the edge point D of Armhole Line upon the armhole girth named PD Line.

(3). The third size measurement was defined from the corner point O of Centre Block Line to the edge point A of Across Back Line upon the armhole girth named OA Line.

(4). The fourth size measurement was defined from the corner point O of Centre Back Line to the edge point B of Back Armhole Line upon the armhole girth named OB Line.

These four extra size measurements were 32.8cm and 32cm in the halved back pattern block and 36.5cm and 33cm in the halved front pattern block. Figure 5.25 shows that the pattern was adjusted by four extra size measurements. Point A was the joint point for two size measurements: 18.5cm, full across back and 32.8cm, an adjusted size of OA dash line. Hereupon OA dash line moved to the expected position by joining the two size measurements at point A. Meanwhile the OB dash line was achieved by following the movement automatically. Therefore the PC dash line and the PD dash line were completed as it was performed in the back pattern block. The black dash-dot-dash line was the resultant pattern which was able to fulfil the 31 size measurements exactly. Therefore the accurate pattern block of skin-fit-knitted jersey garment for posture 1 was shown in Figure 5.26.

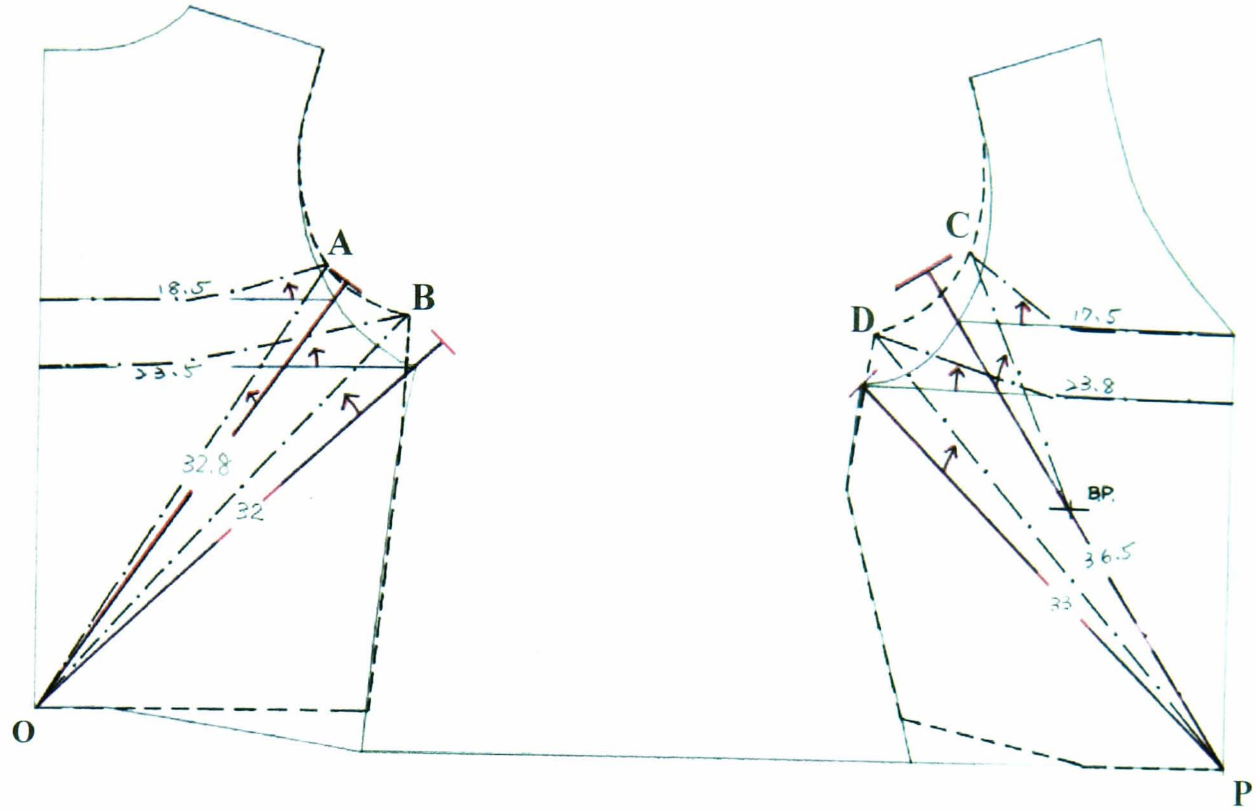


FIG. 5.25 Pattern adjustment by four extra size measurements. Points A and B, D, C were the joint points for size measurements and points O and P were the static points.

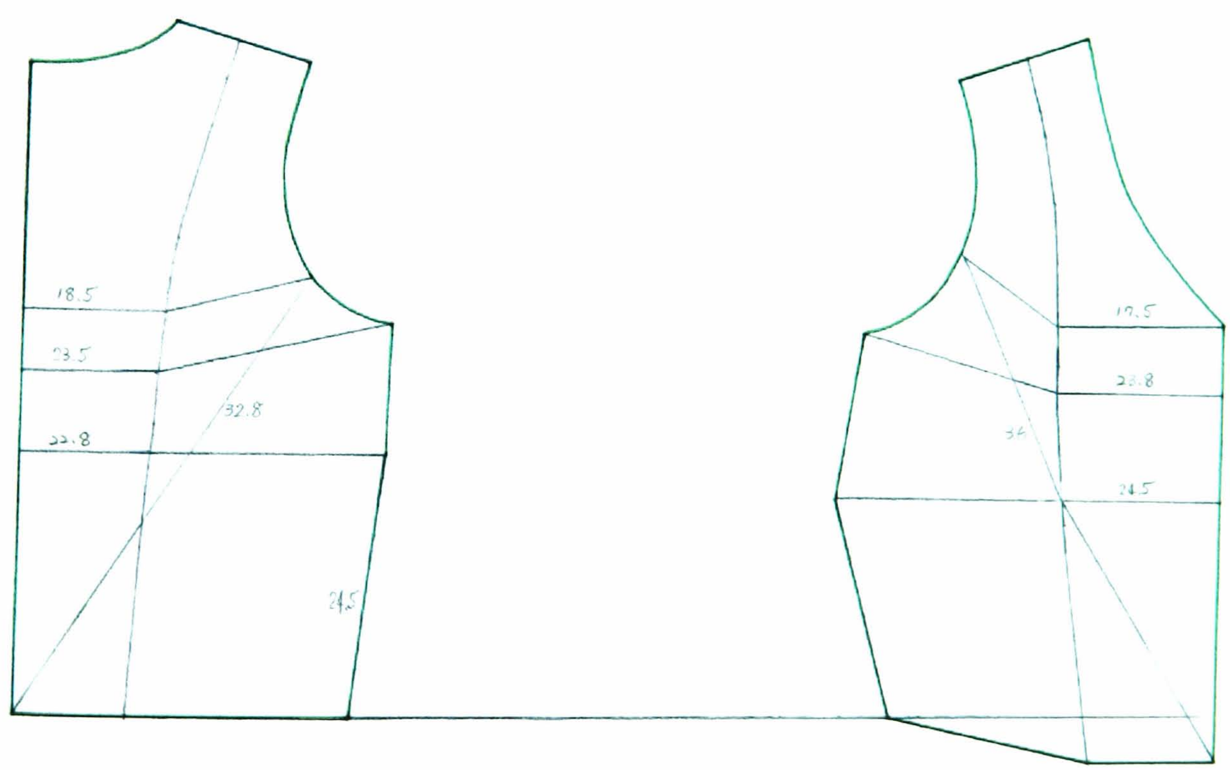


FIG. 5.26 The accurate pattern block of skin-fit-knitted jersey garment for posture 1 was named knitted pattern 1, and achieved by fulfilling the 31 size measurements.

Further the accurate pattern blocks of skin-fit-knitted jersey garment for postures 2 to 5 were completed as illustrated in Figures 5.27a and 5.27b for posture 2. Figure 5.28a and 5.28b for posture 3, Figure 5.29a and 5.29b for posture 4, Figure 5.30 for posture 5. In the study the accurate pattern block of the knitted jersey garment for five postures were named knitted patterns 1 to 5. Sequentially all five knitted pattern blocks of the select jersey garment were presented the further pattern development for woven stretch garment will investigated hereupon.

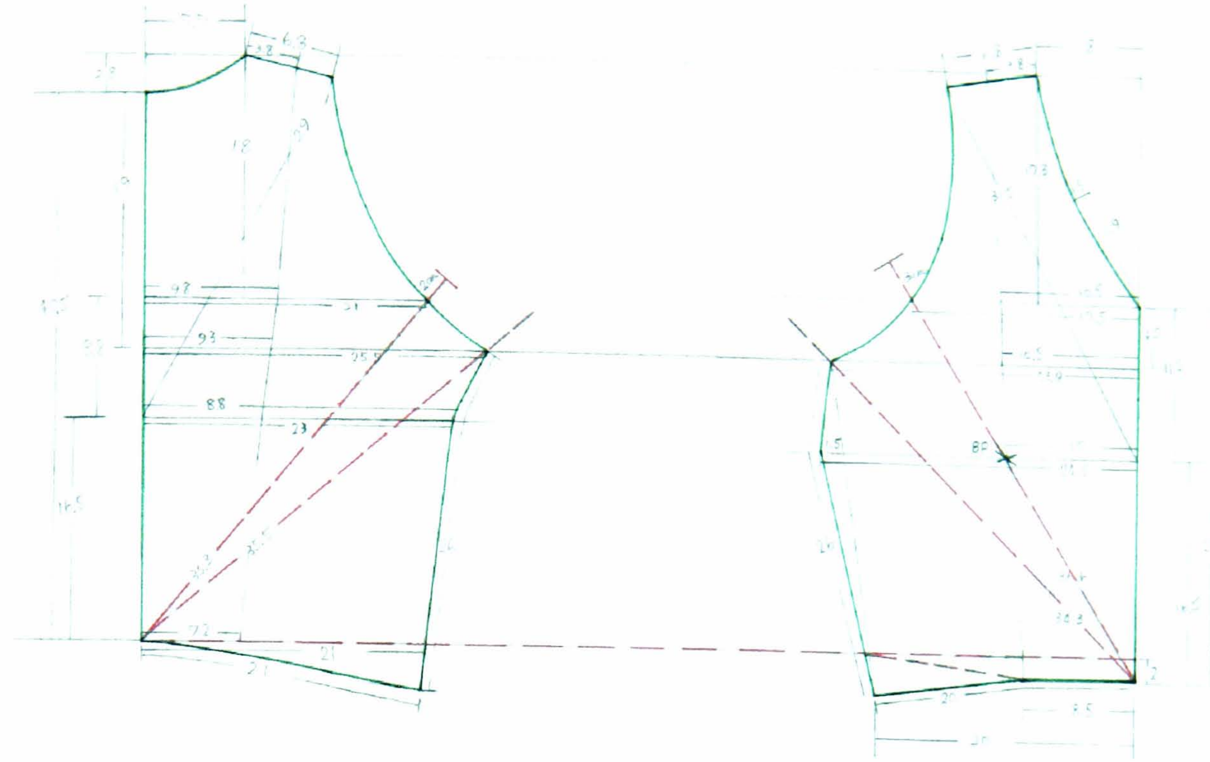


FIG. 5.27a This is the initial drafted pattern block of the knitted jersey garment for posture 2. The 27 size measurements and four adjusted size measurements are expressed in this diagram.

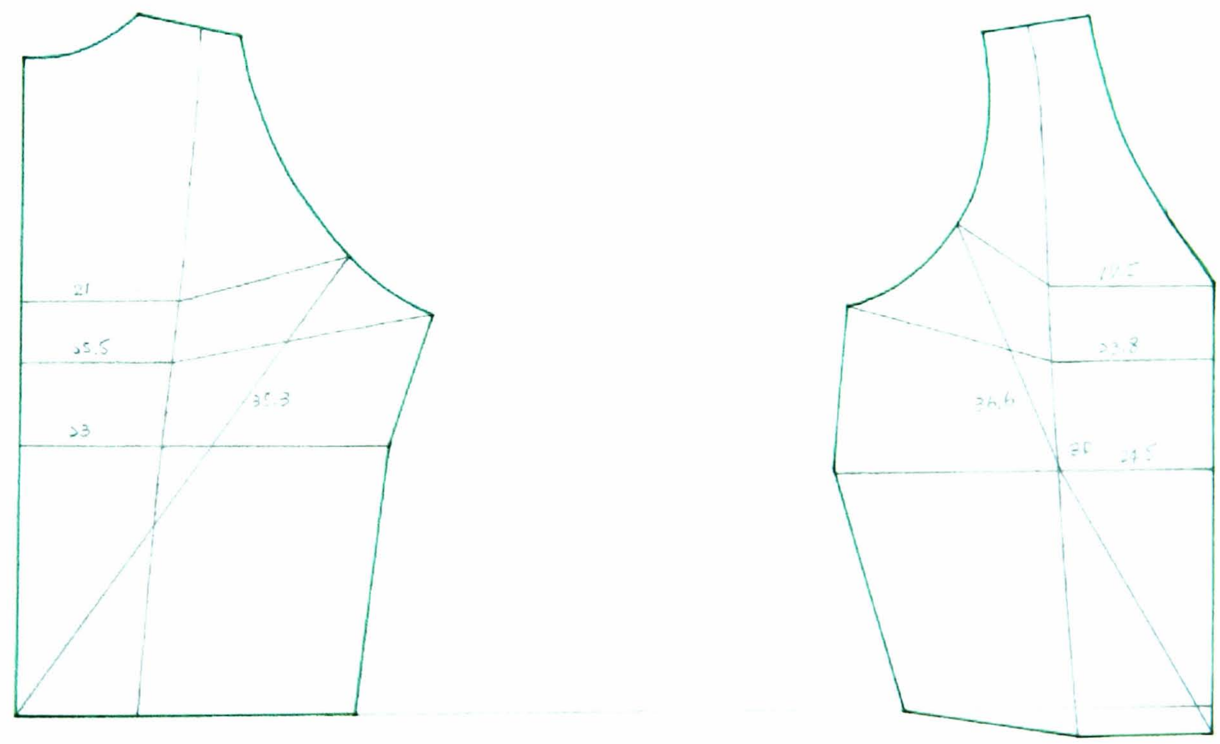


FIG. 5.27b The accurate pattern block of skin-fit-knitted jersey garment for posture 2 was named knitted pattern 2, and achieved by fulfilling the 31 size measurements.

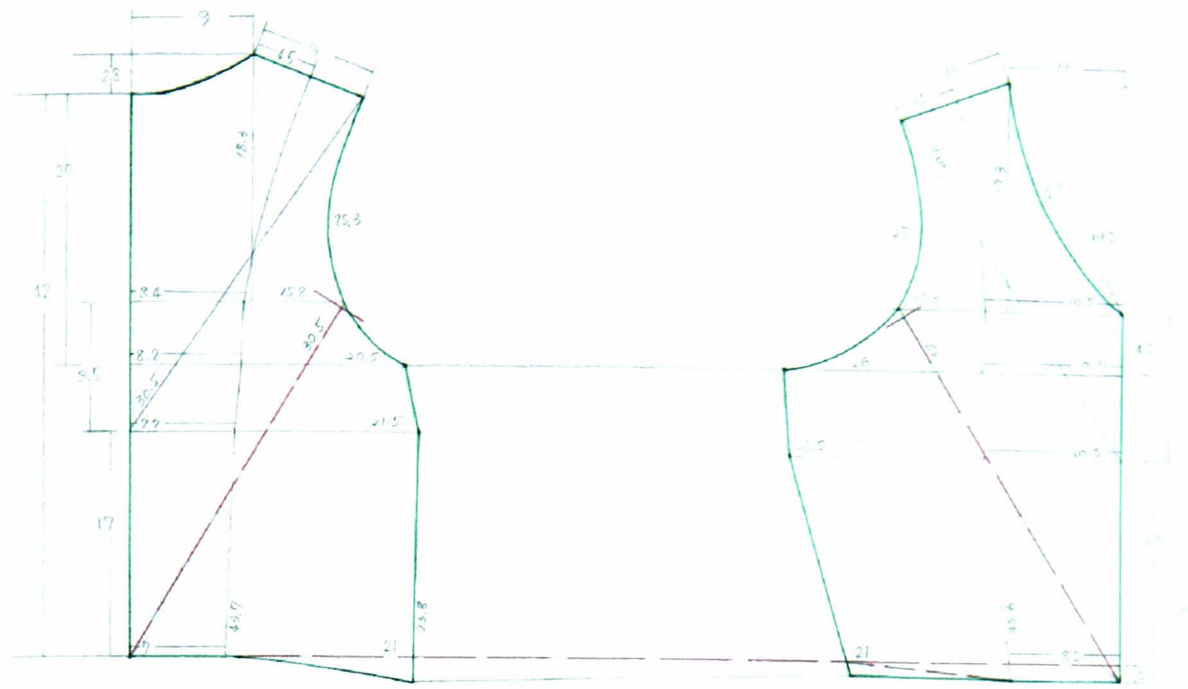


FIG. 5.28a This is the initial drafted pattern block of knitted jersey garment for posture 3. The 27 size measurements and four adjusted size measurements are expressed in this diagram.

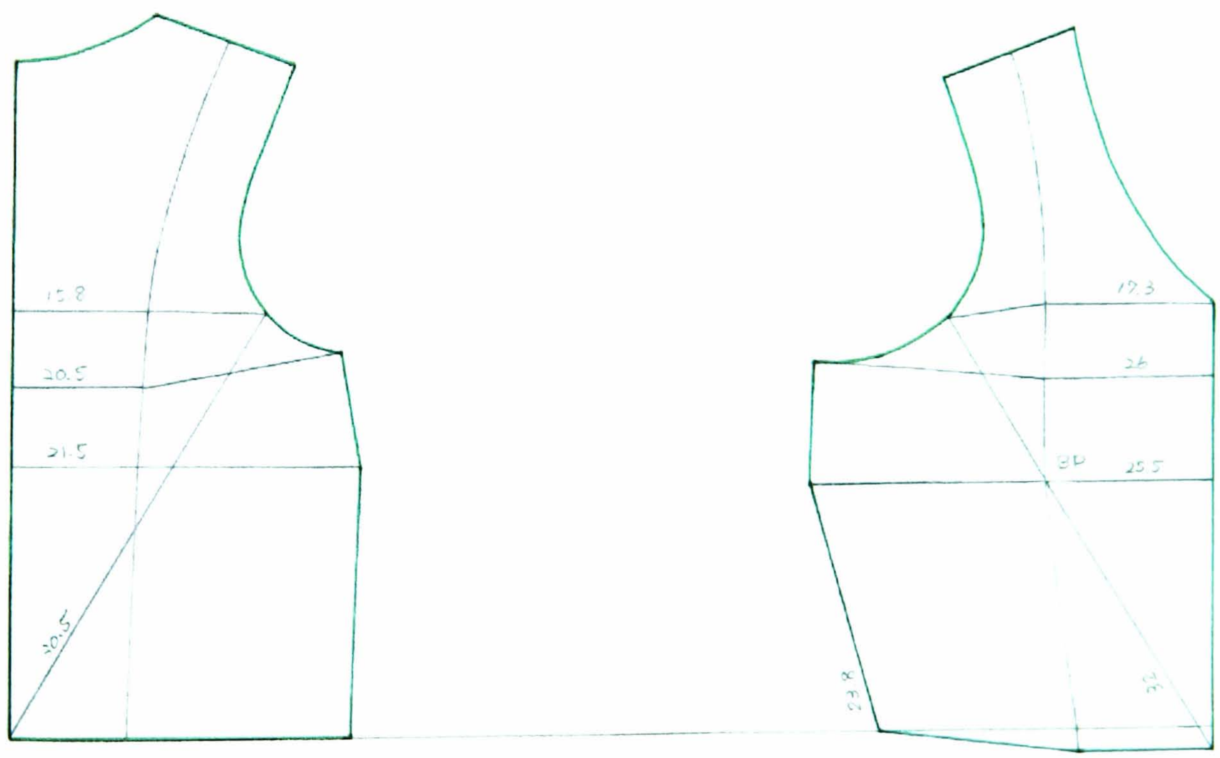


FIG. 5.28b The accurate pattern block of skin-fit-knitted jersey garment for posture 3 was named knitted pattern 3, and achieved by fulfilling the 31 size measurements.

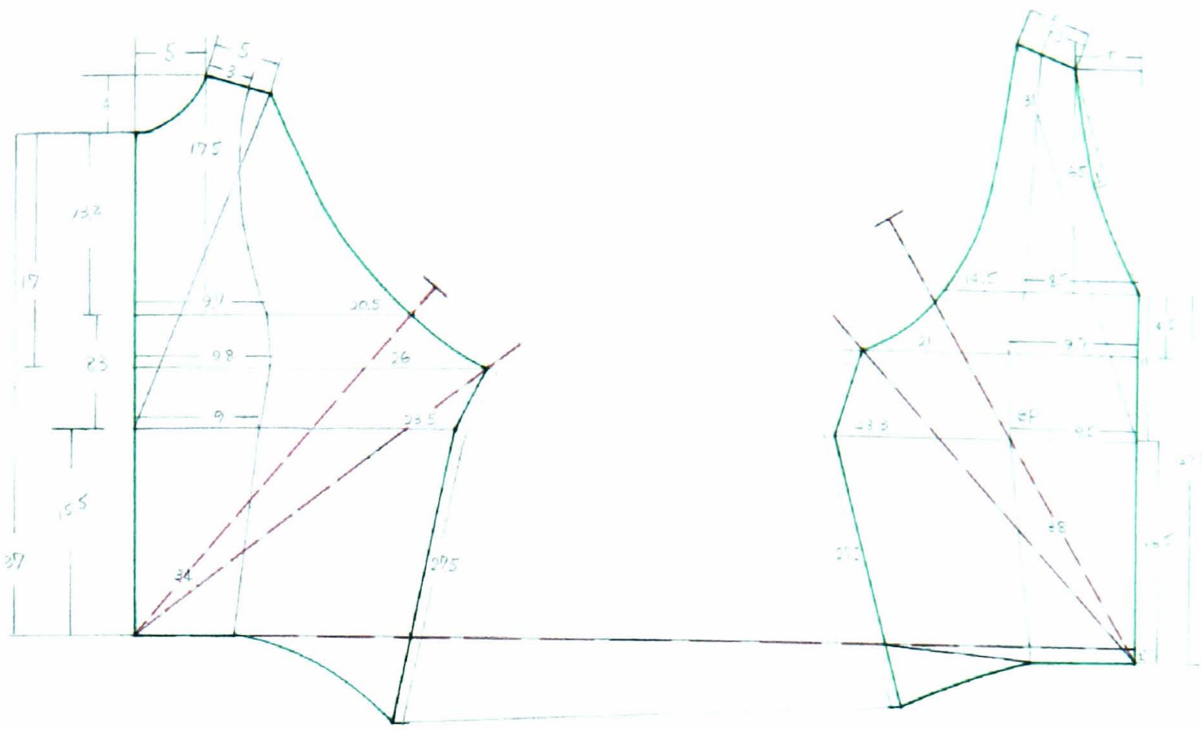


FIG. 5.29a This is the initial drafted pattern block of knitted jersey garment for posture 4. The 27 size measurements and four adjusted size measurements are expressed in this diagram.

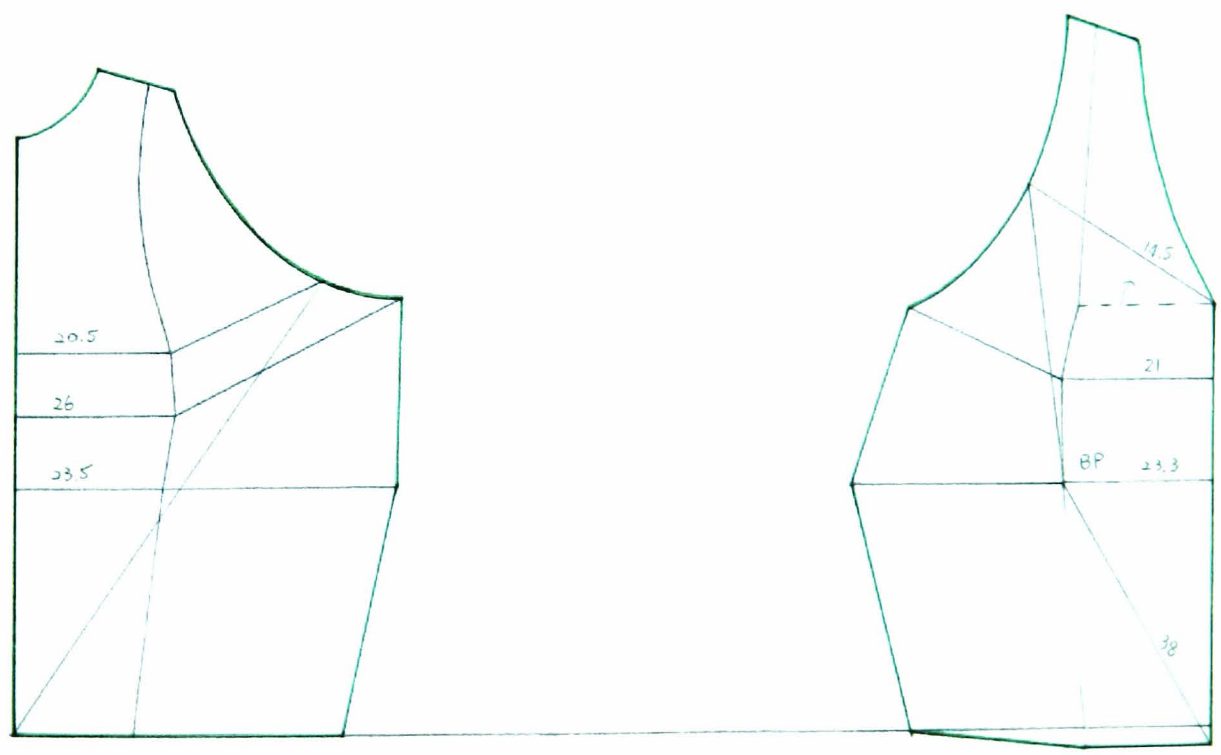


FIG. 5.29b The accurate pattern block of skin-fit-knitted jersey garment for posture 4 was named knitted pattern 4, and achieved by fulfilling the 31 size measurements.

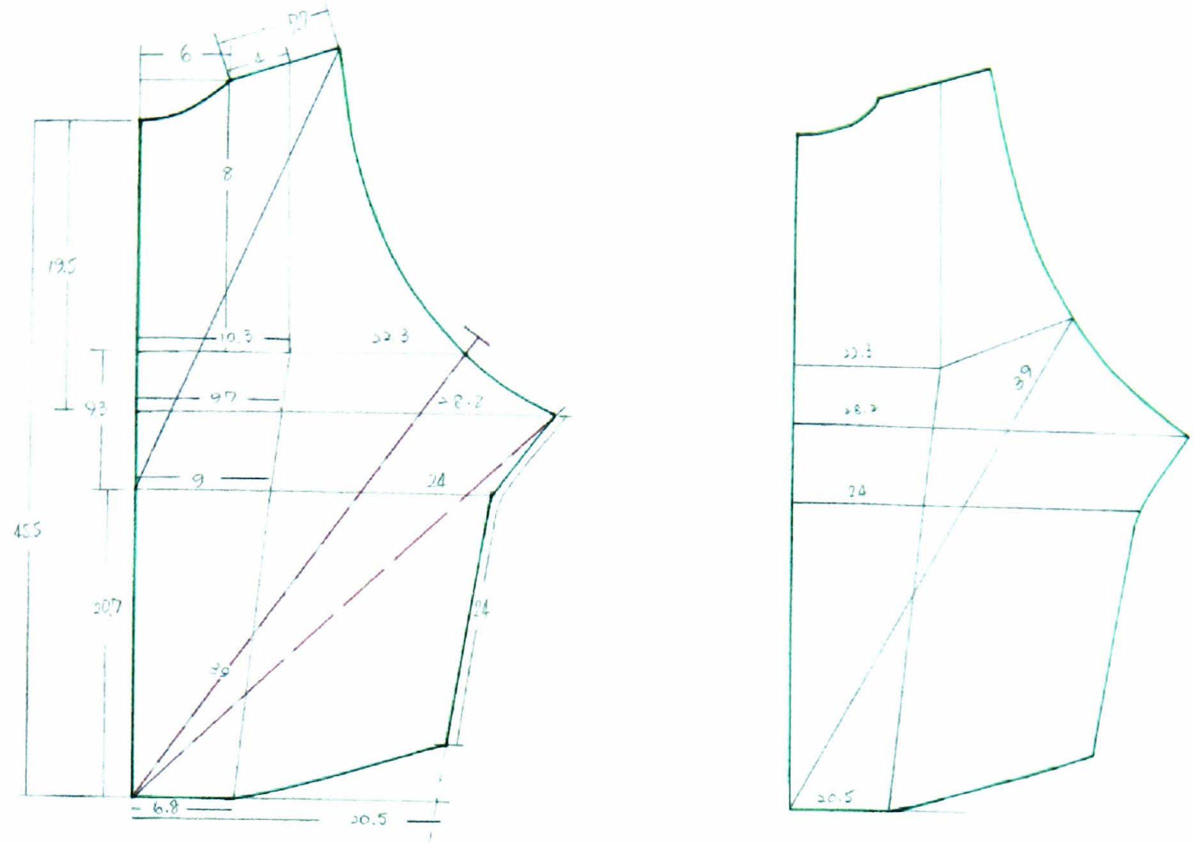


FIG. 5.30 The left pattern block is the initial drafted pattern block of knitted jersey garment for posture 5 (the back pattern block). The required size measurements and the four adjusted size measurements are expressed in the diagram.

5.5 Pattern Development of Woven Stretch Garment

5.5.1 Objective

The objective of this investigation aims to develop a final pattern block for woven stretch fabric. It was highly dependent on the individual fabric stretch and recovery properties. According to the level of fabric extension (refer to Chapter 4), the required pattern reduction and alteration was investigated.

Examining and presenting the five knitted pattern blocks of specified jersey garment for woven stretch fabric was the start of the pattern development process. After the pattern examination all knitted pattern blocks were converted into tailored pattern blocks as they were formed in woven pattern blocks. A required basic pattern block for generating woven stretch garment was then obtained by combining the requirements and benefits from both woven and converted knitted patterns. The pattern block contained the minimum ease requirement and garment shape (introduced by a woven pattern) and the maximum and minimum boundaries of the pattern frame for body movement (introduced by the five knitted patterns). The woven pattern was developed by following tailored woven pattern cutting techniques (refer to Section 5.3) and the converted knitted patterns were achieved through the pattern detection process presented in this Section. The idea of applying skin-fit-knitted pattern was carried out from modelling the knitted fabrics upon a human figure to reproduce the body dimension completely.

5.5.2 Pattern Development and Modification of Woven Stretch Princess-line Dress

The five knitted patterns obtained from the five different postures were discussed in Section 5.4. Figure 5.31 shows the pattern block of the woven princess-line dress (Figure 5.12) and converted knitted pattern 1 (Figure 5.26). In the pattern blocks of the converted knitted pattern the conversion has been carried out by line cutting and opening for introducing the required darts. In Figure 5.31 the BP point down to the lower part of princess line (XY) was cut and opened to introduce the dart into the lines of BP to X and BP to Y in the front pattern block. The BP point of the front pattern block was used as the static point for conversion of all the knitted pattern blocks into the tailored pattern forms. The same amounts of darts used in the front and back pattern blocks of the woven princess-line dress were applied to the knitted patterns. Due to the opening up operation, the Bust Line from the BP point to the S point was moved up, known as a folded paper dart. Therefore the required dart for accommodating the body figure was achieved. In the back pattern block, the OP point was the static point for all knitted pattern conversions. The back princess line was cut from the point OP down to the Waist Line, and opened up for the dart requirement. The opened lines from the point OP to the points M and N are shown in Figure 5.31. The line from the OP point to the T point followed the same operation to fold up.

Consideration was given to the difference in length, which appeared between the front trunk length and the back trunk length. In Figure 5.31, the lengths of the front trunk and the back trunk can be identical in the knitted pattern blocks because the knitted fabric can be easily stretched to fit the body shape, and the difference in these lengths can be negligible. But a tailored woven pattern block has to consider the length difference between front and back trunks. Comparing the length between knitted and woven garment patterns, it can be seen that the length in the front pattern block for a knitted jersey garment is longer than that for a woven garment, but it is the opposite for the back pattern block. Therefore the alteration took place by a reduction of length in the front and an increment in the back to meet the same length of the woven garment pattern. Similarly, the knitted patterns 2 to 5 for Postures 2 to 5 were also converted into the tailored pattern forms by following the same procedure. The results of the converted knitted patterns 2 to 5 are presented in Figures 5.32 to 5.35. All the converted knitted pattern blocks were in the same form as woven garment pattern block (see Figure 5.12). Therefore the next step of pattern development was to overlap all the pattern blocks together to generate a new basic pattern block which is able to meet the requirements of body movement.

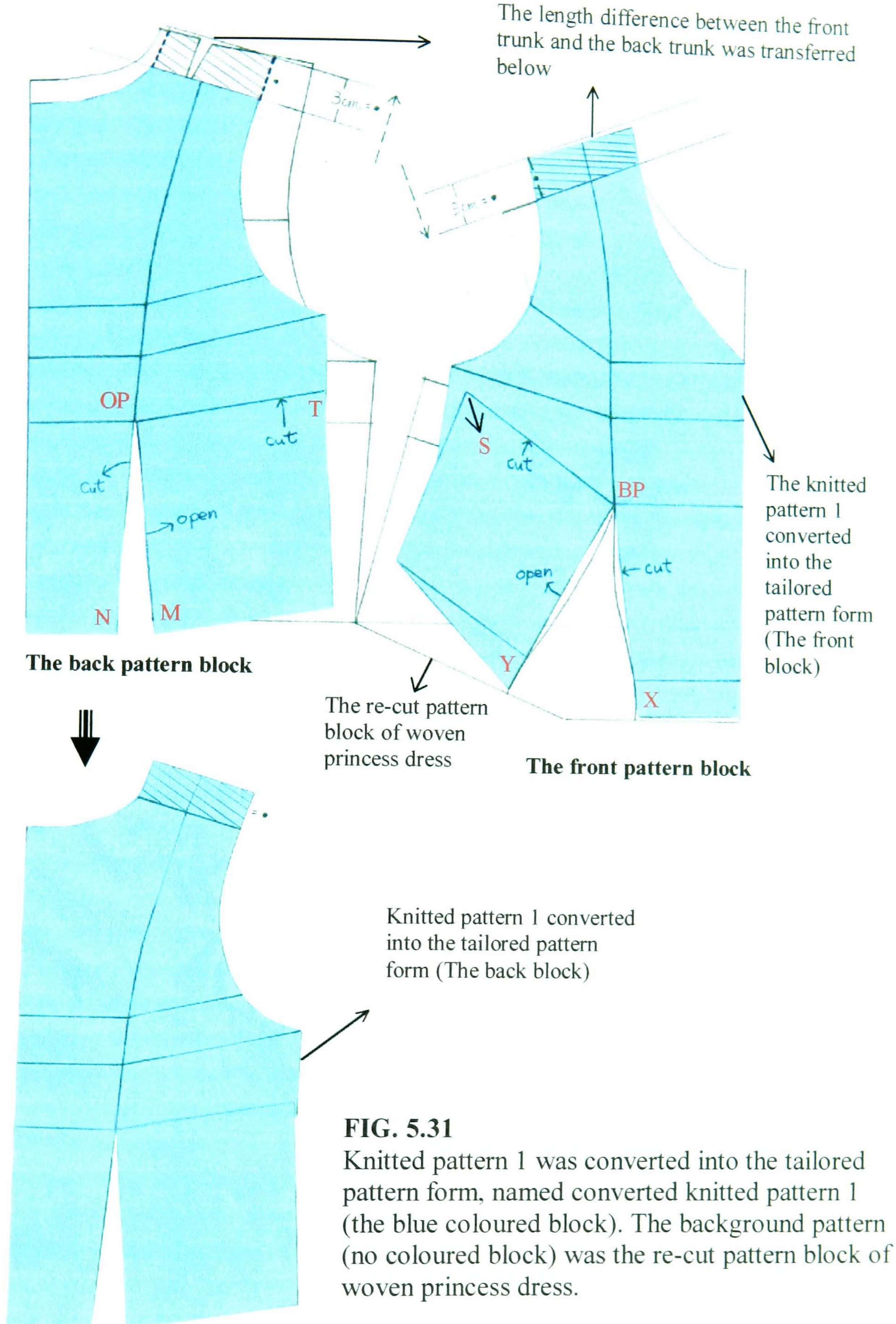


FIG. 5.31
Knitted pattern 1 was converted into the tailored pattern form, named converted knitted pattern 1 (the blue coloured block). The background pattern (no coloured block) was the re-cut pattern block of woven princess dress.

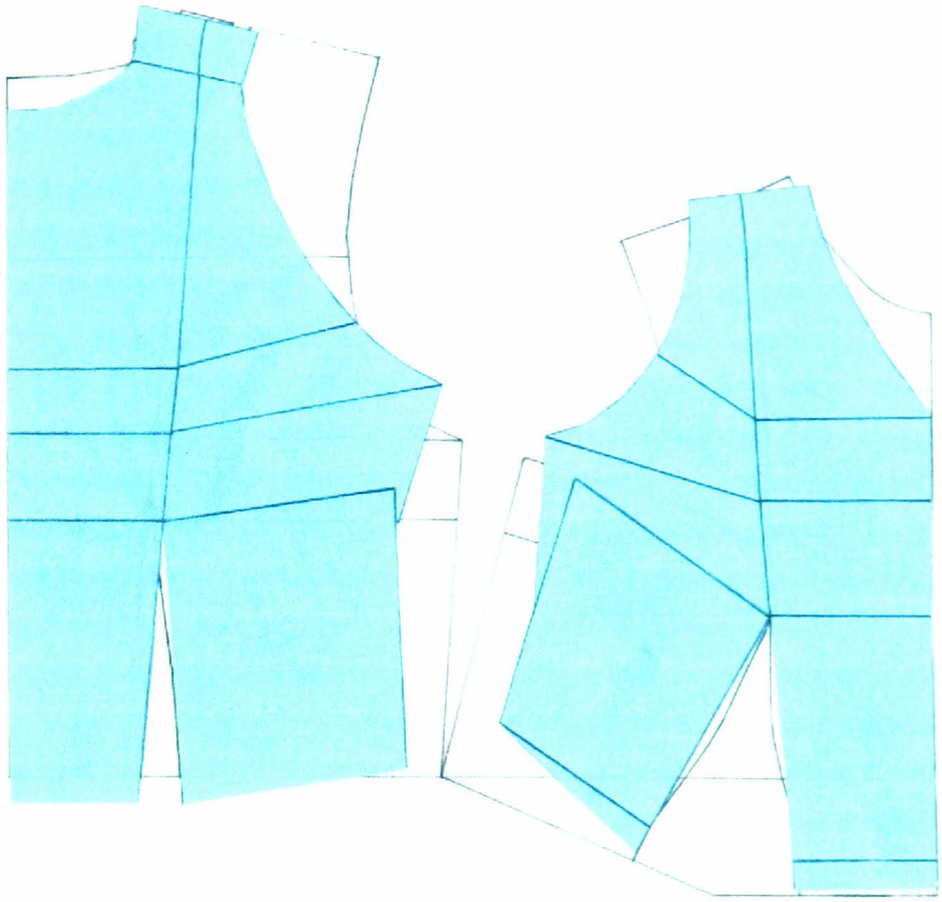


FIG. 5.32 Knitted pattern 2 (the blue coloured block) was converted into the tailored pattern form, named converted knitted pattern 2.

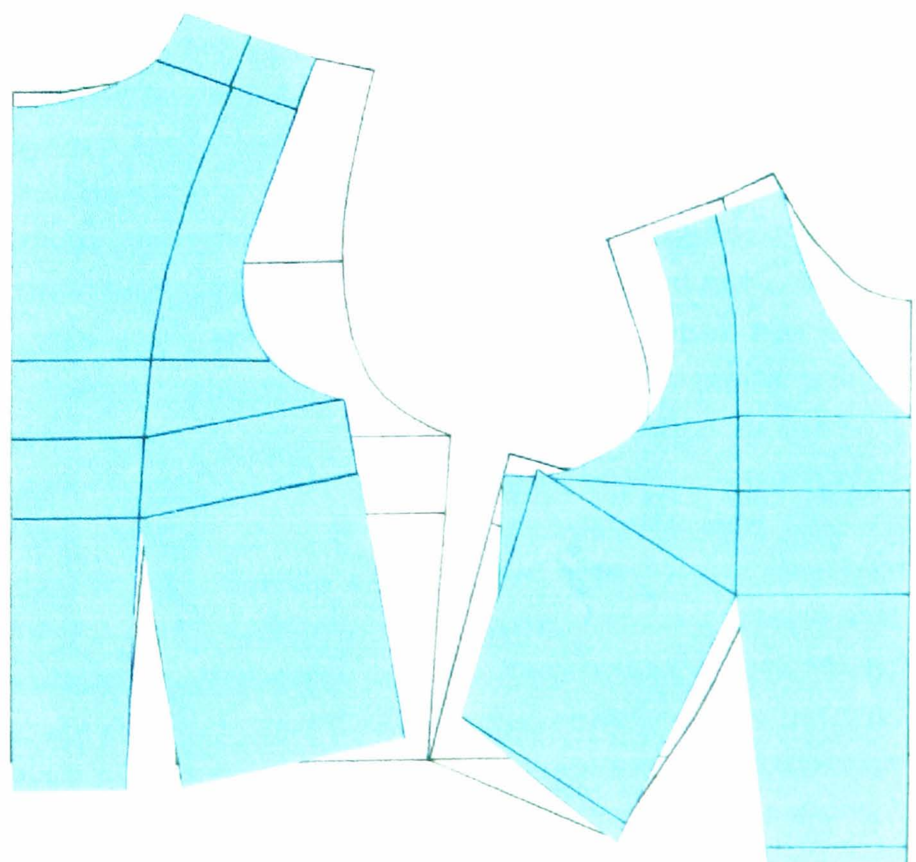


FIG. 5.33 Knitted pattern 3 (the blue coloured block) was converted into the tailored pattern form, named converted knitted pattern 3.

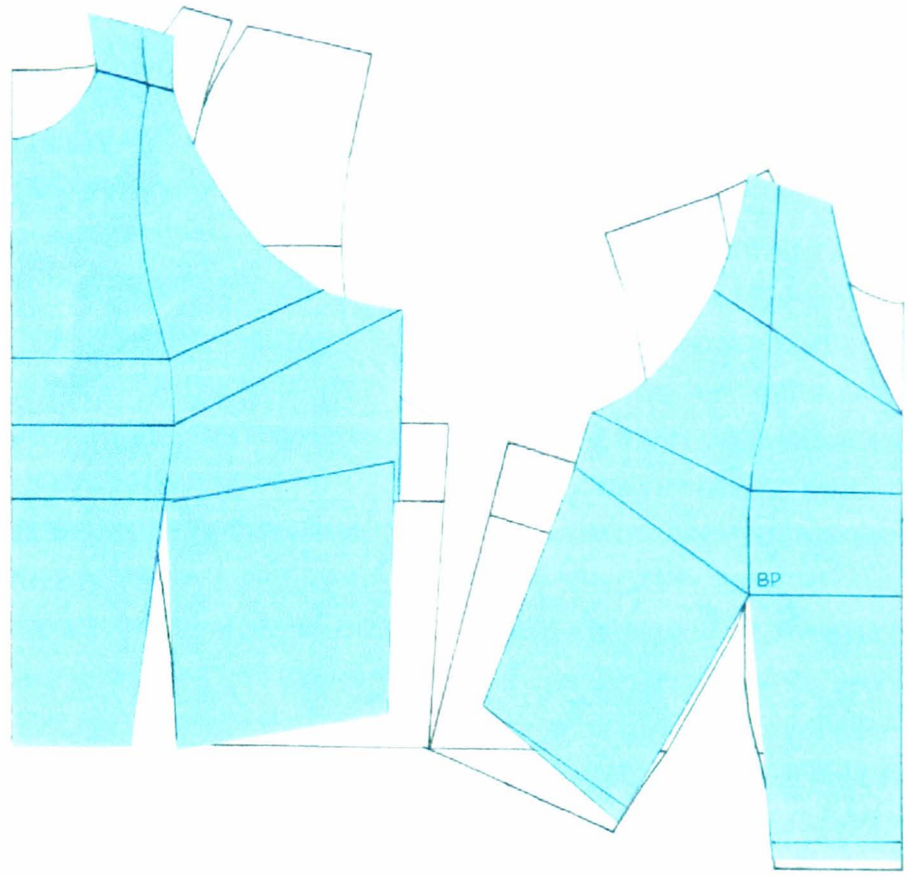


FIG. 5.34 Knitted pattern 4 (the blue coloured block) was converted into the tailored pattern form, named converted knitted pattern 4.

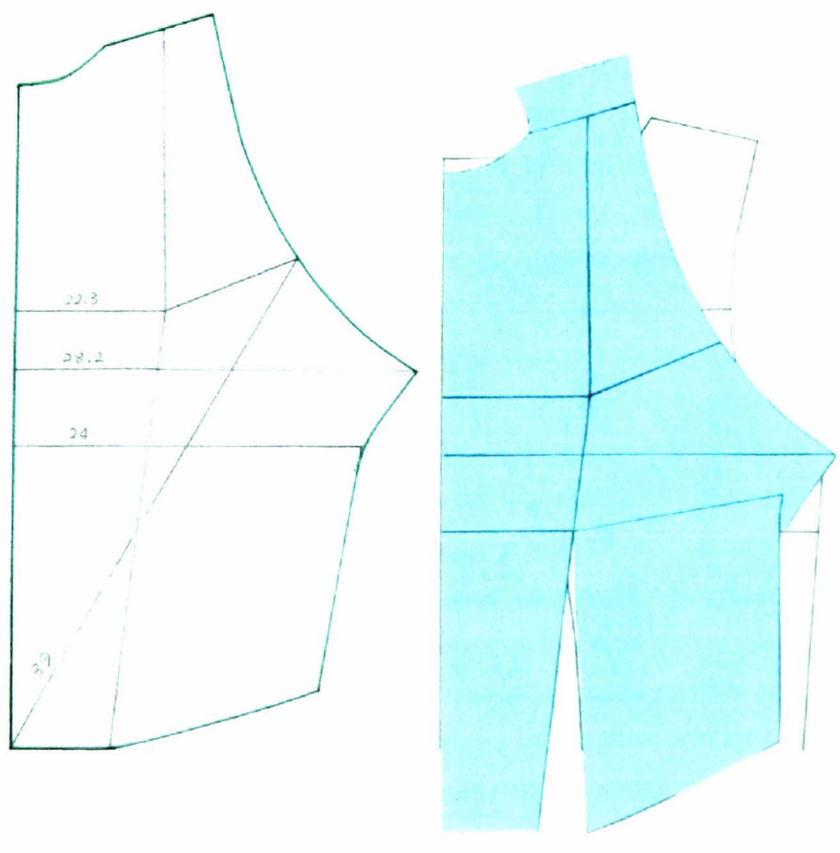


FIG. 5.35 Knitted pattern 5 (the blue coloured block) was converted into the tailored pattern form, named converted knitted pattern 5 (back only).

Figure 5.36 shows that five converted knitted pattern blocks (solid lines) and one tailored woven pattern block (dash line) were overlapped altogether. Considering the woven garment shape, the armhole girths were extended to cover the extended armpit points of the five converted knitted pattern blocks. An overall pattern block required for body movement was produced. Figure 5.37 shows that the difference in the pattern blocks between the original tailored woven pattern (dash line) and the newly obtained pattern block from the overlapped five converted knitted patterns (solid line). The minimum and maximum boundaries for pattern blocks are clearly shown. The pattern alteration for woven stretch garment was based on the minimum pattern block and sizes of measurement lines as shown in Figure 5.38. Therefore the sizes of these measurement lines can be obtained by measuring the minimum pattern block of the woven princess-line dress as given in Table 5.6.

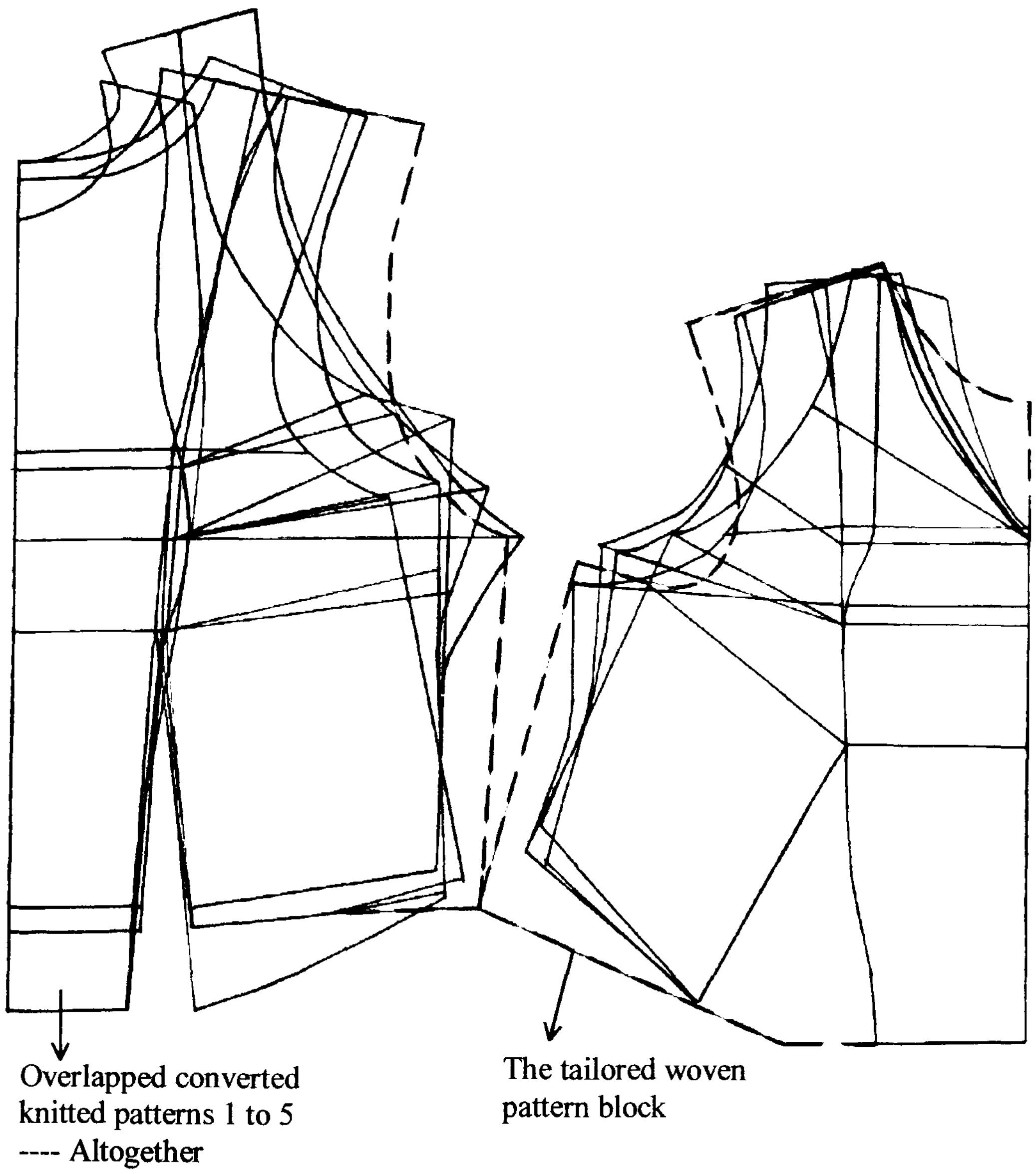


FIG. 5.36 The tailored pattern blocks were overlapped together with the tailored woven pattern block. The purpose of this was to obtain a correct basic pattern block of woven stretch fabric.

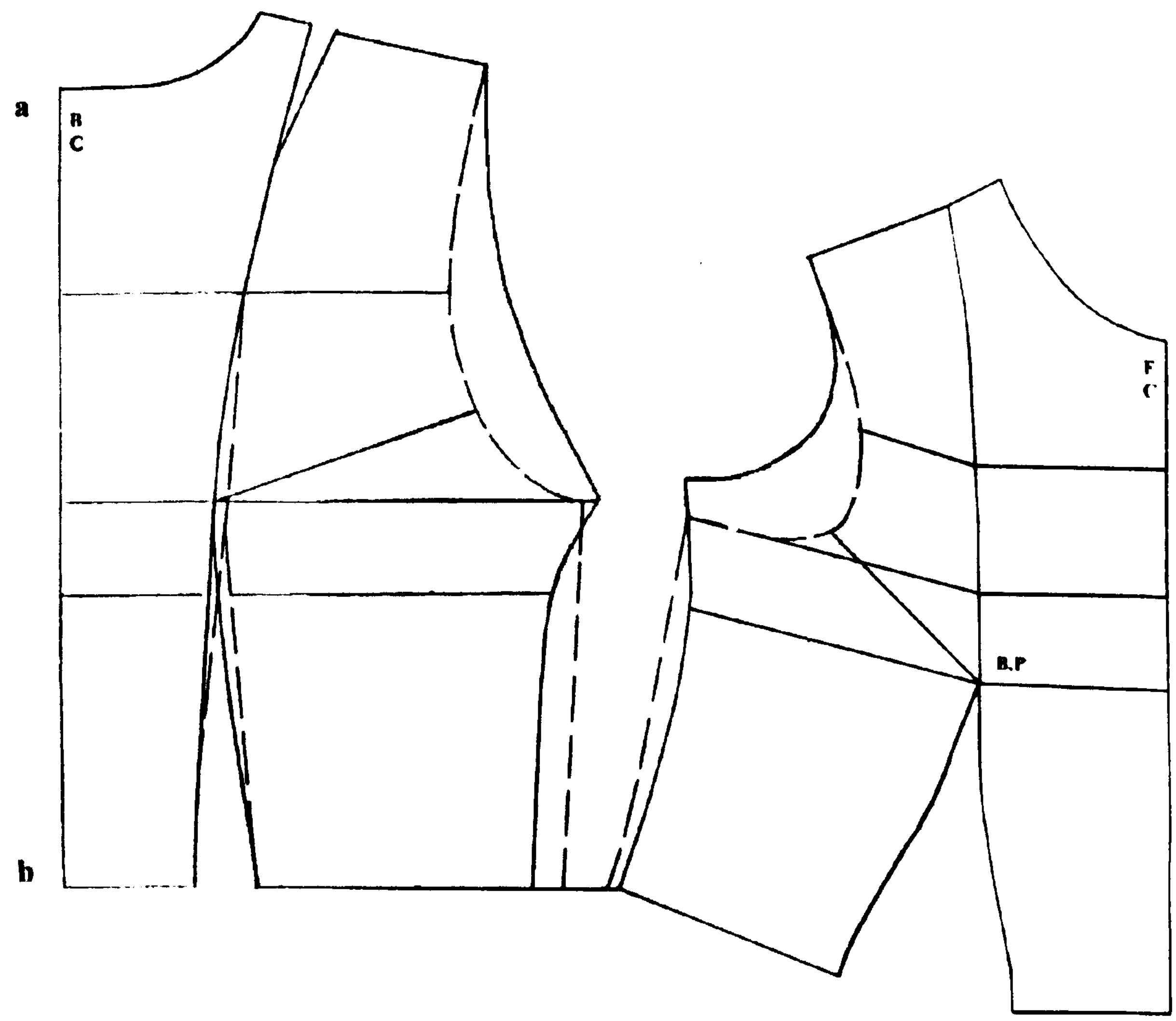


FIG. 5.37 The pattern block of the woven stretch princess-line dress, in practice, was produced through the pattern modification and development from traditional woven pattern and active body movement, skin fitted pattern block (no ease allowed).

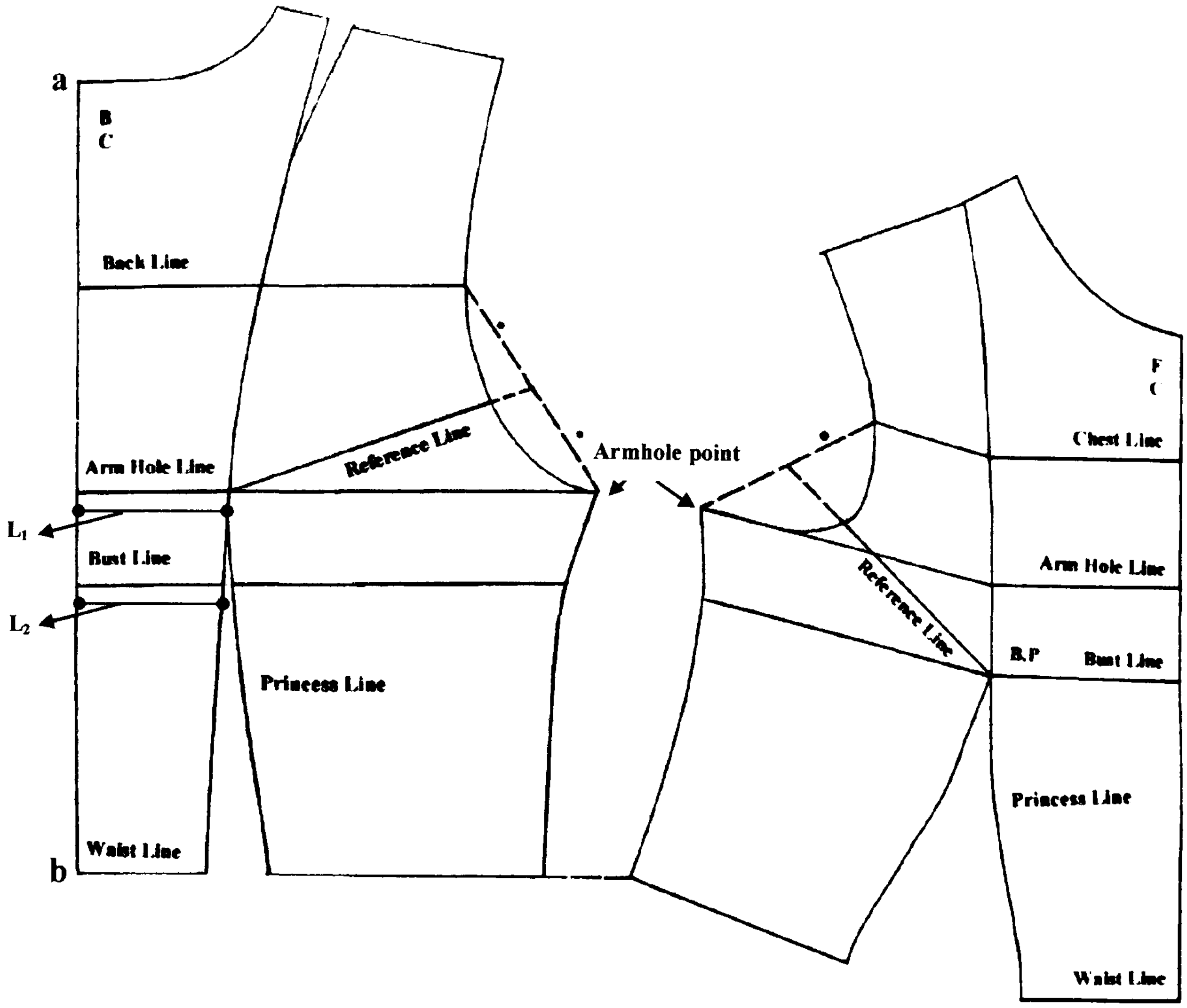


FIG. 5.38 The terms definition and measurement lines in the basic pattern block of woven stretch fabric used to help to apply pattern reduction formulas (and understanding maximum pattern extension allowance) and required pattern alteration correctly with the garment design and styling details.

Table 5.6 Sizes of the measurement lines measured from the minimum pattern block of the woven princess-line dress (Figure 5.38)

Front Pattern Block		Back Pattern Block	
Measurement Line	**Length (cm)**	**Measurement Line**	**Length (cm)**
Chest Line	15.8	Back Line	19.9
Reference Line	12.5	Reference Line	13.75
Armhole Line	20.0	Armhole Line	27.0
Armhole point to Waist line	20.0	Armhole point to Waist line	20.0
Bust line	26.5	Bust line	24.95
Waist Line	20.75	Waist Line	20.55
Princess Line	-	Princess Line	$L_1 = 8.25$ $L_2 = 8.0$
Length of a to b	-	Length of a to b	40.5

The woven stretch fabric D will be used to manufacture the princess-line dress and pattern alternation. The extension and recovery properties of fabric D were discussed in Chapter 4. The accepted extension levels for fabric D in warp, weft and 45°-bias directions are determined on their residual extensions less than 3% as discussed in Section 4.4.2. The results are given in Table 5.7.

Table 5.7 Acceptable Extension Levels of Fabric D in warp, weft and 45°-bias directions of fabric

Fabric Direction	Accepted Extension Level (%)	Residual Extension (%)	Elastic Recovery (%)
warp	20	1.35	93
weft	20	2.3	88
45°-bias	30	2.2	92

Therefore, the garment of fabric D is able to stretch to some degree according to the Acceptable Extension Levels. The extension level for garment pattern in the horizontal can be estimated using the formula below and the results are described in Table 5.8.

• **Horizontal Pattern extension allowance (cm)**

= Size Measurement of Pattern Width (L) X Percentage Extension of Accepted Level (E)

Table 5.8 Extension allowance (cm) of individual reference marks in the front and back pattern

• **The Front Pattern Block:**

Reference Mark⊕	Length+ cm (L)	Percentage Extension of Accepted Level* (E)	Extension Allowance (LxE) cm
Chest Line (weft)	15.80	20%	3.16
Reference line (45°-bias)	12.50	30%	3.75
Armhole line (weft)	25.75	20%	5.15
Armhole point to Waist line (warp)	20.00	20%	4.00
Bust line (weft)	26.50	20%	5.30
Waist line (weft)	20.75	20%	4.15

• **The Back Pattern Block:**

Reference Mark⊕	Length+cm (L)	Percentage Extension of Accepted Level* (E)	Extension Allowance (LxE) cm
Back line (weft)	19.90	20%	3.98
Reference line (45°-bias)	13.75	30%	4.125
Armhole line (weft)	27.0	20%	5.50
Armhole point to Waist line (warp)	20.0	20%	4.00
Bust line (weft)	24.95	20%	4.99
Waist line (weft)	20.55	20%	4.11
Princess line L_1 (weft)	8.25	20%	1.65
Princess line L_2 (weft)	8.00	20%	1.60

Note ⊕ Reference Mark is determined in Figure 5.38

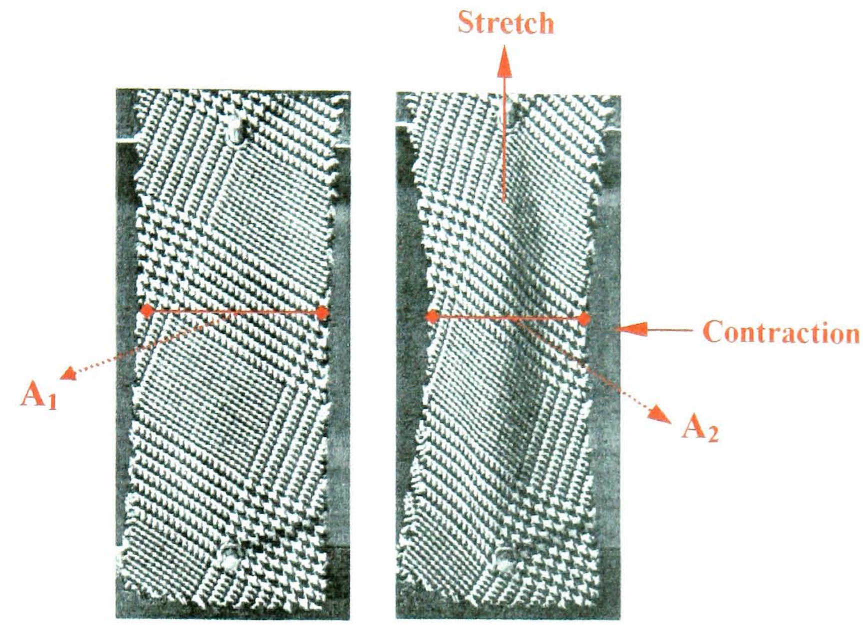
+ Length is recorded in Table 5.6

*Percentage Extension of Acceptable Level is determined in Section 4.4.2 (see Table 4.3)

When fabrics of garment are subjected to force in the vertical direction and stretch to some degree, the contraction of fabric dimension in the warp direction occurs as shown in Figure 5.39. The percentage contraction was calculated below.

$$\text{Percentage Contraction} = \frac{A_1 - A_2}{A_1} \times 100$$

Where: A_1 is the initial sample width
A_2 is the contracted sample width



a. un-stretched sample **b.** stretched sample

FIG 5.39 Contraction of fabric dimension in the warp direction occurs while the fabric was stretched at weft or 45°-bias directions.

In the garment, not only the weft direction but also the 45°-bias direction stretches will affect the contraction of fabric in the warp direction. Therefore the length of the garment has to be considered on the effect of other direction stretches. The vertical pattern extension allowance was calculated as expressed below and the results were shown in Table 5.9.

• **Vertical Pattern additional length (cm)**

= Size Measurement of Pattern Length (L) X Percentage Contraction in warp direction (D)

Table 5.9 Effect of fabric stretch in weft and 45°-bias directions on dimension contraction of fabric D in warp direction

weft stretch	Fabric Dimension Contraction (warp direction)	45°-bias stretch	Fabric Dimension Contraction (warp direction)
0%	0 %	0 %	0 %
5%	0 %	5 %	0 %
10%	0 %	10 %	1.2 %
20%	1 %	20 %	6 %
30%	4 %	30 %	14 %
40%	5 %	40 %	21 %

The length for the woven stretch garment pattern in vertical direction is complemented on the average level of Fabric Dimension Contractions under weft and 45°-bias stretches. Table 5.10 shows that the additional length of garment was added to the dress pattern for complement.

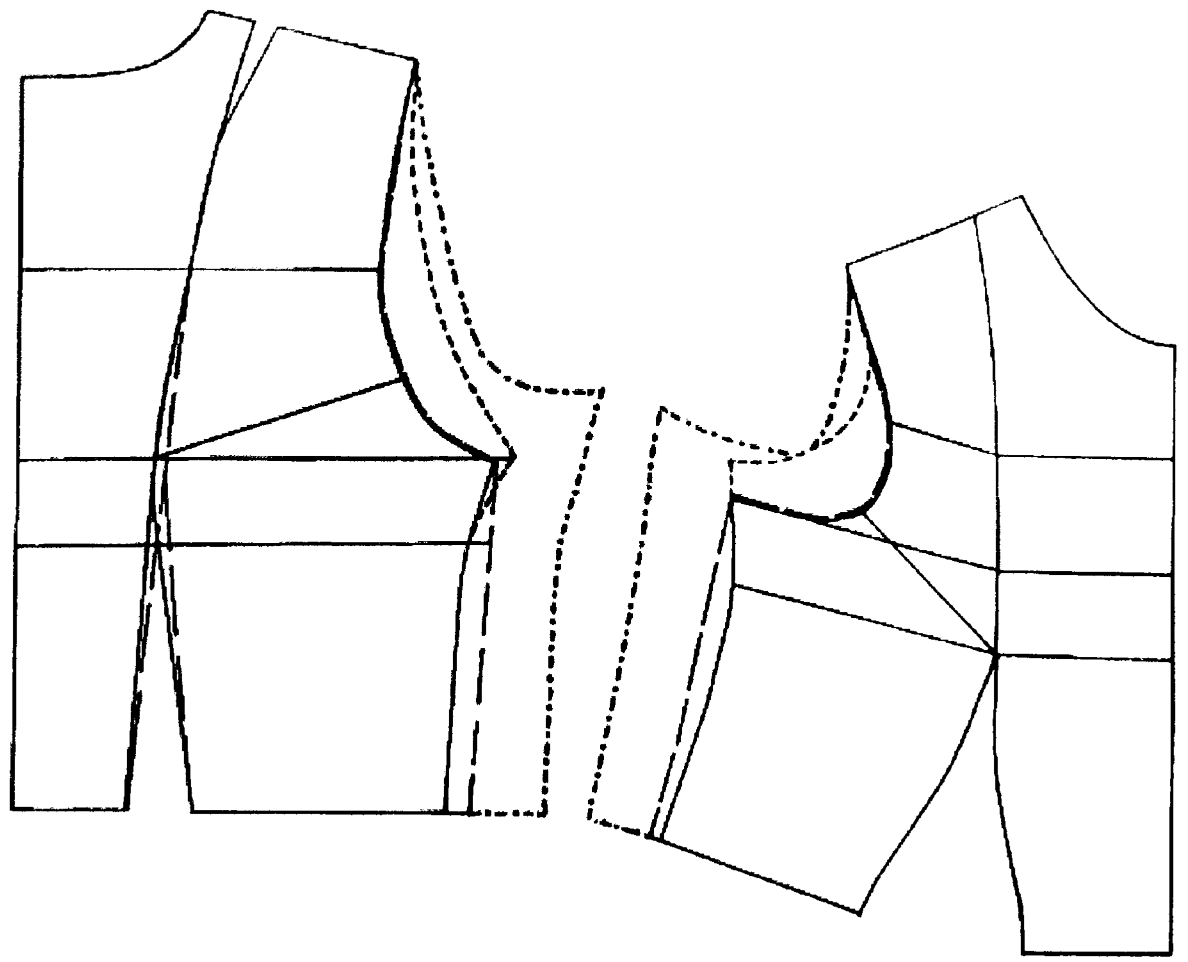
Table 5.10 Additional length was added and adjusted from Back Pattern Block:

Reference Mark⊕	Length+ cm (L)	Percentage Contraction Level of warp* (D)	Addition cm (LxD)
Length of point **a** to pint **b**	40.5	3.5 %	1.4

Note ⊕ Reference Mark is determined in Figure 5.38
+ Length is recorded in Table 5.6
* Percentage Constraction Level of warp is an average of Percentage Contraction under 20 % stretch in weft and 45°-bias directions (see Table 5.9)

Figure 5.40 shows the patterns of a final princess-line dress for fabric D (solid line). According to acceptable extension level of fabric D, the dress pattern is actually able to stretch to the level of the dash-dot-dash line pattern. It was found that the extension level (dash-dot-dash pattern) covers the overall converted knitted pattern block (dash line) for the requirement of comfort for the five body movements. In the front pattern, the margin between the extension level and the overall converted knitted pattern block is very small in the area of armhole girth. Therefore Fabric D with 20 % acceptable extension level in weft direction for the alternated pattern can just achieve both the required level of comfort to allow for the five body movements proposed in the project and also a better fitted silhouette of garments. If the acceptable extension level of a woven stretch fabric is less than 20 %, the woven stretch garment can meet only one of these criteria either a fitter silhouette of a garment or better comfort for body stretch by adding sufficient ease to achieve this level. But the garment of woven stretch fabric in fitted pattern can achieve body movement with less extent of stretch.

The garment from the final princess-line dress pattern for fabric D will be further assessed objectively and subjectively to confirm the fit and comfort criteria as discussed in Chapter 6.



— — Pattern A -- the pattern block of woven princess-line dress

——— Pattern B -- the pattern block of woven stretch princess-line dress

- - - - The overall converted knitted pattern block

- · - · - The maximum extension allowance of woven stretch princess-line dress (at acceptable extension level of 20 %)

FIG. 5.40 Illustration of all pattern blocks

5.6 Conclusions

In this chapter, five typical postures were defined to represent the range of body movement and stretch. The body sizes under different postures were determined by tape measuring and 3D body scanner. The accuracy of data obtained from the body scanner was evaluated. It was found that the size measurements from scanner/computer were very close to the data from tape measurement. But the 3D Body scanner was not able to detect some hidden body sizes of the bending postures.

The effect of body movement on garment stretch and fabric distortion was investigated. The results gave detail to information on the degree of fabric/garment distortion during body movements with consideration of garment slippage. This will be very useful for garment design and pattern construction.

Based on a basic pattern block, the extension and recovery properties of woven stretch fabrics were taken account for pattern reduction and alteration. The garment pattern for woven stretch fabrics was generated to meet not only a fitter silhouette of a garment but also better comfort for body movement. The new generated pattern model can also be used for the woven stretch fabrics with different extension and recovery properties by altering the boundary of the pattern. Therefore the garment pattern can be predicated and produced according to the extension and recovery properties of fabrics. The trial and error procedure might not be necessary.

6

GARMENT EVALUATION

CHAPTER 6

GARMENT EVALUATION

6.1 Introduction

The creation of a "second skin" to a body shape can only be achieved by the use of stretch fabrics, which can expand and contract without buckling or wrinkling to accommodate body movement. Currently stretchable garments can be divided into three categories: comfort stretch garments, stretch to fit garments and power stretch garments. Each of these categories will require a different degree of extensibility and a different range of stress-strain properties. Woven stretch garments can be found within these three categories, depending on the degree of their extension and recovery. These three categories are described below.

1. *Comfort stretch garments* are well fitting and some garments in this class may have stretch properties due to their construction and/or fibre content. Their properties of extensibility are designed to accommodate body movements particularly around the elbows, knees, waist, back and seat where, for certain body movements, the fabric is stressed.
2. *Stretch to fit garments are* designed to fit closely to the body contours without exerting any figure shaping pressure. Generally these garments are produced from knitted or jersey fabrics. Woven stretch garments are sometimes also expected to perform some figure shaping function.
3. *Power stretch garments* exert some control over the shape of the body by exerting some compressive pressure on the surface. They may also be used to support various parts or may be used for medical reasons.

The demand for stretch garments is a result of an increased interest in fitness, comfort and fashion (Losa, 1980). Woven stretch garments have stretch and recovery properties different to woven and knitted garments. Nowadays the traditional methods of pattern construction for woven stretch fabric are unable to meet current requirements of fit and not considered as reliable scientifically. Hereupon being able to improve the pattern generation of woven stretch garments the suitable evaluations were applied. Within the garment evaluation process, the wearer trial is an evaluation for the wear durability of a garment. It is a measure of a garment quality. A major factor in garment quality is the time for which an article may be expected to last. The garment lifetime may be a function of several factors, among which is the rate at which a garment fails. In the project the stretch and recovery properties of the fabric will be the main factor of its quality which affects the appearance of fit. Furthermore clothing is worn for many reasons, all of which influence to some extent the mental or physical comfort and fit of the wearer. When a garment is discarded, its rejection may therefore simply be a matter of fashionability or may be caused by a physical deterioration (into localised holes or worn patches) that makes the wearer reject it. This latter type of change is the one addressed in the first part of the evaluation here. In the project the assessment contains two parts, one being an evaluation on the size change of garment pattern and the other one is an evaluation of the wearer appearance, comfort, fit, and durability. Four garments were produced, two from fabric D and two from fabric S, by one operator on a single needle domestic sewing machine.

Many judges and theorists (Fan, 1997, Kawabata and Niwa, 1991) have successfully established the methods of evaluations and assessments. However, their approach and analytical methods on evaluation of garment performance are very complicated. In this chapter, the four garments were assessed by both objective and subjective methods for appearance and fit. Two objective assessments for taking garment measurements were used in the project. The first method is a manual measurement by using tape measurement (or gauge measurement) and the second is a computer measurement by using the Tri Form® TorsoScan system. Two periods of wearer trial test were scheduled. The first test period was planned within an hour performance and the second was planned over an 8 hour performance of a day at least. Furthermore a garment evaluation task was judged and issued subjectively from 40 experienced fashion and textile designers by showing videotape of the specified wearer wearing each garment in a sequence of the ranged postures.

6.2 Objective

The objective of this chapter is to assess the reduced and altered pattern block generated for woven stretch garments as described in Chapter 5. The new generated pattern will be evaluated objectively and subjectively with the traditional woven garment pattern. The garment distortion and change in pattern size during wearing will be investigated. The benefits of the garments for the woven stretch fabrics will be discussed. The feedback results will be reflected to the modified pattern for further improvement in the future.

6.3 Garments Making for Evaluation

6.3.1 Stability in Body Size of the Model over the Period of this Project

The present work for the pattern design, modification and wearing trial was carried out over a period of 10 months. Stability in model's body size over the period of the project is very important for results consistency and reliability. Therefore the model size was monitored during the period of research. Table 6.1 shows the six main size measurements of the appointed model within the investigative period of this project from 29th April 1999 to 15th January 2000. It was found that model kept her body size and shape very well. There was no significant change in major body size. 'Side hip depth' and 'Back length' remained same. The standard deviations for variations in bust line, waist line, abdomen and hip line show that there is very little change (see Table 6.1). Therefore any factor of body size change could be negligible.

Table 6.1 Size collection of the wearer while exerting the pattern investigation and garment evaluation of the project

Date	Size measurement (cm)					
	Bust line	Waist line	Abdomen	Hip Line	Side hip depth	Back length
29/04/99	97.0	79.0	96.5	97.0	18.0	41.0
17/05/99	97.5	79.5	96.0	97.0	18.0	41.0
20/05/99	97.3	79.0	96.6	97.2	18.0	41.0
26/08/99	97.5	79.5	96.0	97.0	18.0	41.0
10/12/99	97.5	79.6	96.5	97.5	18.0	41.0
29/12/99	97.6	79.8	96.8	97.6	18.0	41.0
30/12/99	97.6	79.8	96.7	97.5	18.0	41.0
31/12/99	97.6	79.8	96.7	97.6	18.0	41.0
01/01/00	97.7	79.8	96.8	97.7	18.0	41.0
07/01/00	97.7	79.7	96.7	97.6	18.0	41.0
10/01/00	97.6	79.6	96.7	97.6	18.0	41.0
12/01/00	97.5	79.4	96.5	97.5	18.0	41.0
15/01/00	97.4	79.4	96.5	97.5	18.0	41.0
Mean	97.5	79.5	96.5	97.4	18.0	41.0
Standard Deviation	0.19	0.28	0.26	0.26	0.00	0.00

6.3.2 Garment Making

In order to evaluate the new generated garment pattern for woven stretch fabric, the princess-line dresses were made according to the traditional and modified patterns respectively. Two type of woven fabrics: woven stretch fabric D and the woven fabric S (see Table 3.1) were used for comparison in the evaluation. Figure 6.1 shows that Fabrics S and D were used to produce Garments A1 and A2 made by a traditional pattern (Pattern A) and also used to produce Garments B1 and B2 made by the new altered pattern (pattern B).

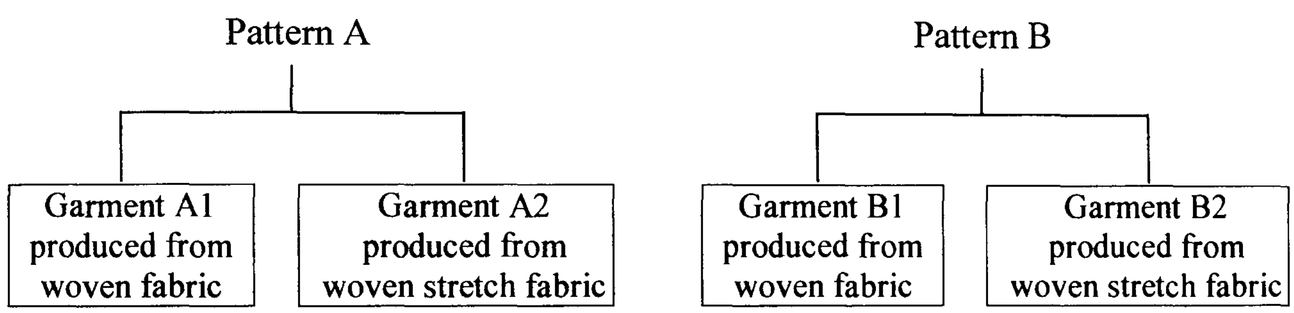


Fig. 6.1 Garments A1 (produced from woven fabric S) and A2 (produced from woven stretch fabric D), both were made in Pattern A, and garments B1 and B2 produced from Fabric S and Fabric D, both were made in Pattern B

In the detail of making princess-line dresses from Patterns A and B, 1cm (3/8″) seam allowance was added to all outside edges. Four garments were produced, two each from fabric D and fabric S. All four garments were placed on both of the cross grain (courses) and the straight grain (wales) of the garment surface at bust, waist, hip, centre front lines, etc. For consistency one operator sewed all four garments with a conventional plain stitched seam on a single domestic sewing machine. For control, all four garments were tried on the same specified wearer as previously mentioned for fitting the garments. To ascertain the fit of the four garments, a visual examination was performed. When judged on the wearer, the four garments all demonstrated the same fit characteristics and provided functional body movement. The design of the assessed garment was kept the same in the project to eliminate problems that would occur in comparing garments of different designs. The garment style chosen was designed to fit the body with the minimal amount of ease that was required. Fit ease and style ease are not necessarily separated in the wearer's or judge's mind with the concept of garment assessment. Where fit ease and style ease are described below:

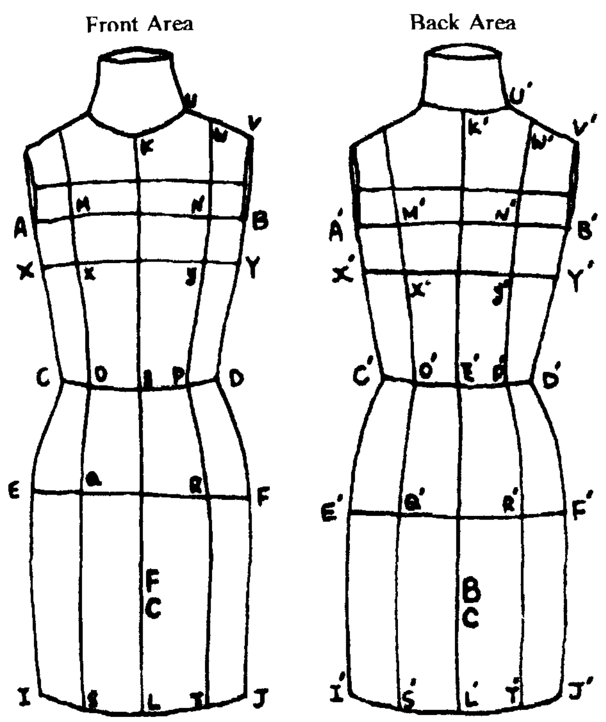
Fit ease is used to accommodate body function by allowing body movement and preventing a garment from bending.

Style ease is the amount of fullness added to create visual effect. Styles ease often results in additional volume to certain body areas, depending upon personal preference and current fashions in various clothing categories.

The four garments were produced for assessment of garment quality and durability, and to insure both fit and comfort for wearers.

6.3.3 Size Verification

Size variation between garments and actual designed patterns could have occurred during the process of manufacturing the garments. In order to reduce the error in size variation, size verifications were applied to confirm all size measurements to be accurate and approximate. Two methods of size measuring were presented. The first method was a tape measurement the second was a computer measurement using 3D body scanner/computer system. Pattern sizes and garment sizes were measured from the specified landmarks illustrated in Figure 6.2. Points A to B were the measurement point of the front body/garment area and the points A' to B' were the measurement point of the back body/garment area.



Measured points	Description (Front Area)	Measured points	Description (Back Area)
KL	front neck to skirt hem	K'L'	back neck to skirt hem
AI=A'I'	under armhole to skirt hem		
UV=UV	side neck to shoulder (sleeve) tip		
AB	front armhole-line girth	A'B'	back armhole-line girth
CD	front waist girth	C'D'	back waist girth
EF	front hip girth	E'F'	back hip girth
IJ	front skirt-hem girth	I'J'	back skirt-hem girth
MN	a measured length upon the front armhole-line	M'N'	a measured length upon the back armhole-line
OP	a measured length upon the front waist girth	O'P'	a measured length upon the back waist girth
QR	a measured length upon the front hip girth	Q'R'	a measured length upon the back hip girth
ST	a measured length upon the front skirt-hem girth	S'T'	a measured length upon the back skirt-hem girth
VW=V'W'	a measured length upon side neck to shoulder (sleeve) tip		
XY	front bust girth	X'Y'	back bust girth
xy	a measured length upon the front bust girth	x'y'	a measured length upon the front bust girth
KZ	a measured length from the front neck to the waist bond	K'Z	a measured length from the back neck to the waist bond

FIG. 6.2 Specified landmarks and their descriptions used for taking garment size measurements

The size measurements of patterns A and B were measured by using two-dimensional tape measurement and three-dimensional body scanner system. The results are shown in Tables 6.2 and 6.3. The tape measurement confirmed that sizes of garments made from patterns A and B were identical to their original pattern sizes. But the body scanner shows that there was only little difference in some sizes. That would not affect the comparison between the garments and patterns.

Tables 6.2 Size collection from an initial flat pattern A and garments A1 and A2 by using tape measurement and computer measurement

Size measurement (cm)					
Garment-marks	Pattern A **(Initial)**	Garment A1 **(Manual)**	Garment A1 **(Computer)**	Garment A2 **(Manual)**	Garment A2 **(Computer)**
KL	76.5	76.5	76.55	76.5	76.55
K'L'	81.5	81.5	81.5	81.5	81.5
AI = A'I'	60.3	60.3	60.4	60.3	60.4
UV = U'V'	11.0	11.0	11.0	11.0	11.0
AB	53.0	53.0	53.5	53.0	53.5
A'B'	53.6	53.6	53.7	53.6	53.7
CD	42.5	42.5	42.5	42.5	42.5
C'D'	44.5	44.5	44.5	44.5	44.5
EF	51.8	51.8	51.9	51.8	51.9
E'F'	55.8	55.8	56.0	55.8	56.0
IJ	56.4	56.4	56.4	56.4	56.4
I'J'	61.0	61.0	61.2	61.0	61.2
MN	19.5	19.5	19.55	19.5	19.55
M'N'	16.6	16.6	16.6	16.6	16.6
OP	17.0	17.0	17.0	17.0	17.0
O'P'	13.8	13.8	13.8	13.8	13.8
QR	20.4	20.4	20.4	20.4	20.4
Q'R'	16.0	16.0	16.0	16.0	16.0
ST	22.2	22.2	22.2	22.2	22.2
S'T'	19.0	19.0	19.0	19.0	19.0
VW = V'W'	7.9	7.9	7.9	7.9	7.9
XY	51.3	51.3	51.3	51.3	51.3
X'Y'	50.6	50.6	50.6	50.6	50.6
xy	19.6	19.6	19.6	19.6	19.6
x'y'	15.6	15.6	15.6	15.6	15.6
K'Z'	40.5	40.5	40.5	40.5	40.5

Tables 6.3 Size collection from an initial flat pattern B and garments B1 and B2 by using tape measurement and computer measurement

Garment-marks	Pattern B (Initial)	Garment B1 (Manual)	Garment B1 (Computer)	Garment B2 (Manual)	Garment B2 (Computer)
	Size measurement (cm)				
KL	76.5	76.5	76.55	76.5	76.55
K'L'	82.0	82.0	82.0	82.0	82.0
AI = A'I'	60.3	60.3	60.4	60.3	60.4
UV = U'V'	11.0	11.0	11.0	11.0	11.0
AB	53.0	53.0	53.5	53.0	53.5
A'B'	53.6	53.6	53.7	53.6	53.7
CD	41.0	41.0	41.0	41.0	41.0
C'D'	41.5	41.5	41.5	41.5	41.5
EF	51.8	51.8	51.9	51.8	51.9
E'F'	55.8	55.8	55.9	55.8	55.9
IJ	56.4	56.4	56.4	56.4	56.4
I'J'	61.0	61.0	61.2	61.0	61.2
MN	19.5	19.5	19.55	19.5	19.55
M'N'	15.6	15.6	15.6	15.6	15.6
OP	17.0	17.0	17.0	17.0	17.0
O'P'	13.8	13.8	13.8	13.8	13.8
QR	20.4	20.4	20.4	20.4	20.4
Q'R'	16.0	16.0	16.0	16.0	16.0
ST	22.2	22.2	22.2	22.2	22.2
S'T'	19.0	19.0	19.0	19.0	19.0
VW = V'W'	7.9	7.9	7.9	7.9	7.9
XY	51.0	51.0	51.0	51.0	51.0
X'Y'	48.2	48.2	48.2	48.2	48.2
xy	19.6	19.6	19.6	19.6	19.6
x'y'	14.6	14.6	14.6	14.6	14.6
K'Z'	40.75	40.75	40.75	40.75	40.75

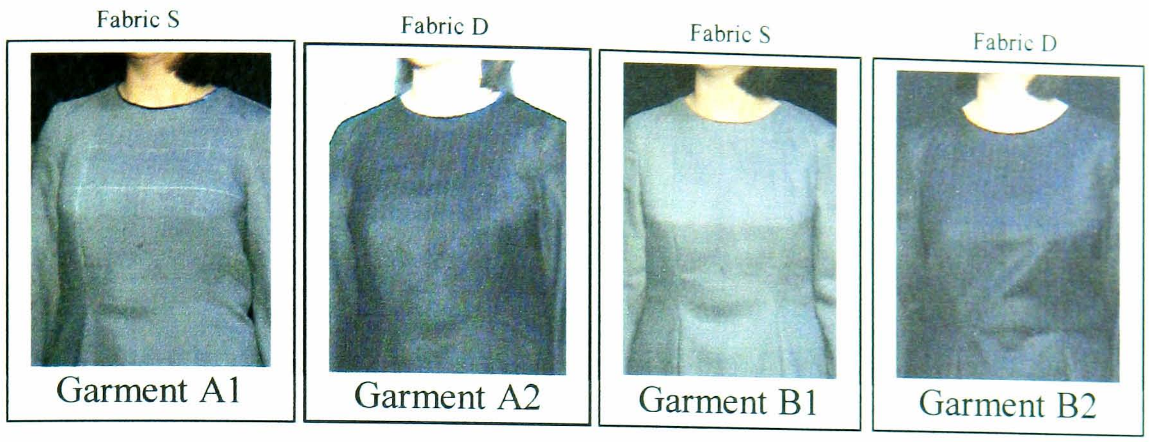


FIG 6.3 Overview of garments A1 and A2, B1, B2 in the standard upright position and dressed on the specified wearer.

Figure 6.3 shows final Garments A1 and A2 based on Pattern A from fabrics S and D respectively and Garments B1 and B2 based on Pattern B from fabrics S and D respectively.

6.4 Objective Evaluation

Woven stretch fabric D and woven fabric S were made to Garments A1 and A2 by following the initial woven pattern and Garments B1 and B2 by following the altered woven stretch pattern, respectively as described in Section 6.3.2. The wearer trial with four garments was carried out by the appointed model whose size the patterns were based on. The first period of wearer trial with normal body movement was an hour, and then the second was over eight hours within a day (see Figure 6.4). Assessments on performance of these four garments were carried out during or after wearer trial. The evaluation is able to serve several purposes in the study.

1. To determine the performance of new woven stretch garments constructed in new pattern construction, in most instances, by comparison with woven garments of known pattern construction (traditional woven pattern construction).

2. To determine the suitability of tested garments in applicable end-uses.

3. To evaluate and compare the interaction of wear and two types of fabrics.

4. To evaluate and compare the interaction of wear and pattern construction to fit each individual fabric stretch and recovery properties.

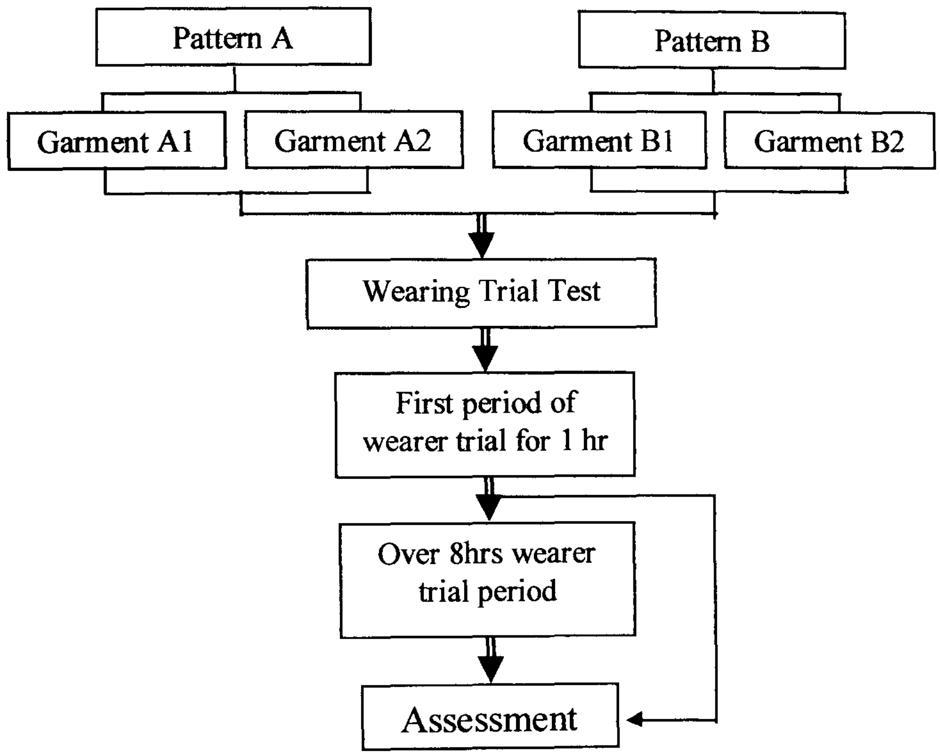


FIG. 6.4 Contextual diagram for model overview

In order to evaluate the woven stretch dress from the new generated woven stretch pattern (Pattern B), the same style of dress from the traditional woven pattern (Pattern A) was used for reference. Therefore, the assessment will evaluate the performance between woven pattern (Pattern A) and reduced woven stretch pattern (Pattern B). Comparison will be also carried out on the garment wear and stretch performance between normal woven fabric S and Fabric D. During the period of the wearer trial, the wearer was asked to practice normal body movements and encouraged to exercise the defined five postures (see Figure 6.5). The effect of patterns and fabric stretch properties on appearance, garment durability and distortion including dimensional stability will be mainly concerned for the assessment during the wearer trial.

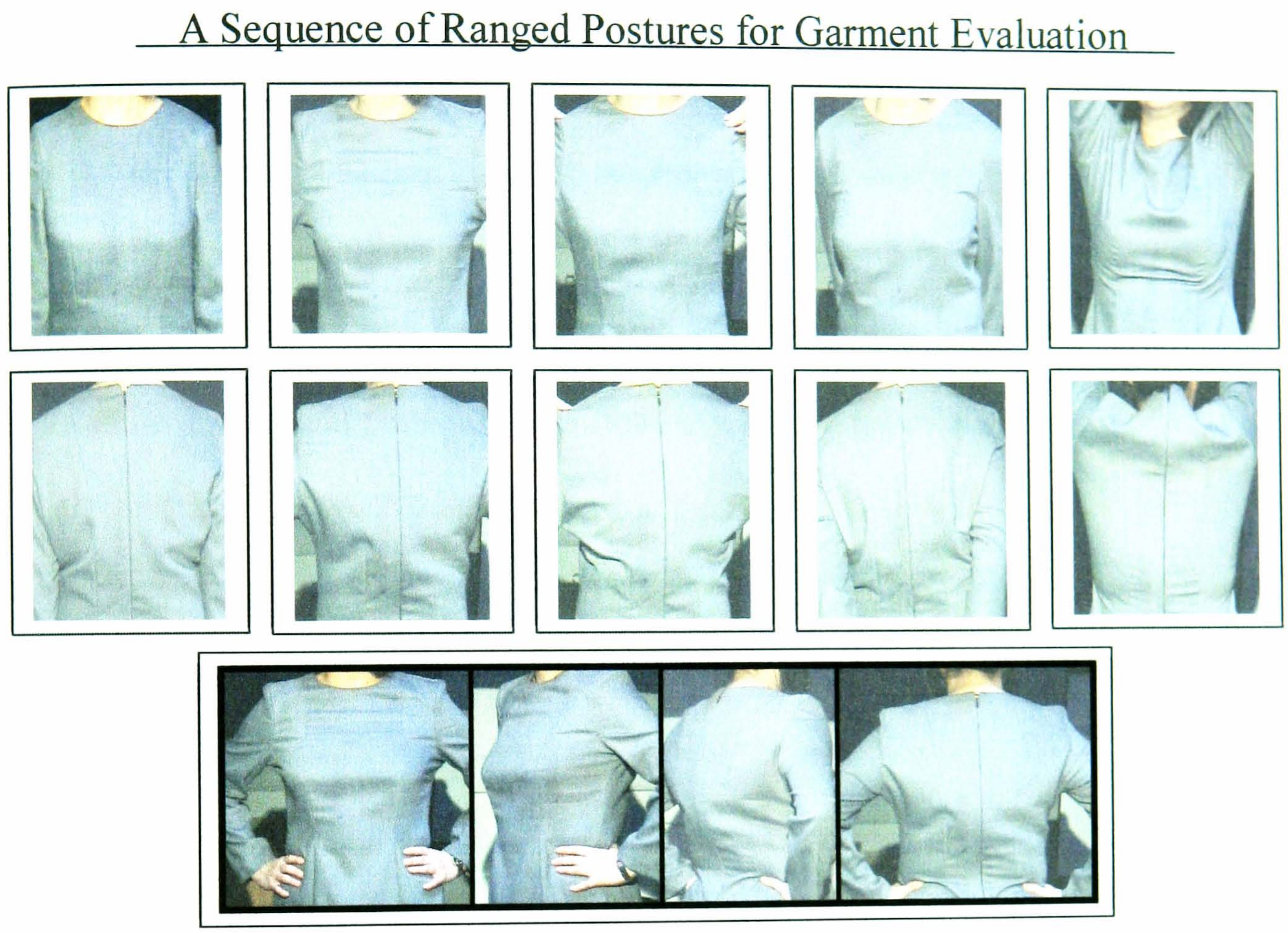


FIG 6.5 Five ranged postures during body movement

Traditional tape measurements were used to measure sizes of girths and lengths of garment segments at upright standing posture during the wearer trials. After every test period of wearer trial, the garments were left at least 24 hours for recovering and regaining the garment dimension. All size measurements were then measured from the garment surface. The measurements were carried out three times and an average was obtained. The garment distortion and size change after the wearer trial were evaluated in the term of "Percentage Size Growth" which was calculated as:

$$\text{Percentage Size Growth (\%)} = \frac{X - Y}{Y} \times 100$$

Where: **X** is the garment size measured after every period of wearer trial.

Y is the initial garment sizes from pattern A or B.

Figure 6.6 shows the size changes of garment A1 after one hour and 8 hours of wearer trial. It was found that there was no increase in the size of garment A1 after 1hr trial, but there was an obvious increase in size occurred after 8 hours' wearing. That was due to the lack of recovery responding to repeat stretch of woven fabric S. The increase was various in different parts of the garment, especially, the front lines of OP, XY and xy, and their back line (Q'R') reaching about 2%. Therefore it was shown that the woven fabric S was not able to keep garment shape even in the unreduced normal woven garment pattern. Woven stretch fabric D was made in the same garment style from pattern A. Its size stability during wearing is shown in Figure 6.7. There was no size growth in the main measured parts of garment (A2) after one and eight hours' wear. It can be seen that the garment in pattern A using woven stretch fabric D was able to meet body movement requirements without causing fabric distortion in the dress, although the garment did not show enough fit for the body shape. The ease was adequate.

The pattern A is normal pattern for woven fabrics. Pattern B was the new pattern, which was generated for woven stretch fabric to meet both fit and comfort as described in Chapter 5. When the normal woven fabric was used to make the garment of pattern B, its performance in express of size growth is shown in Figure 6.8. There was only a small size growth in the one hour trial but significant damage occurred in the 8 hours wearer trial. Size growth in the lines of AB, E'F', M'N' and Q'R' were obvious. A worn and seam-thrown area near the under-arm seam was observed, as shown in Figure 6.9. This had been expected, because the woven fabric S in Pattern A had already shown irrecoverable stretch as occurred in Garment A1. Pattern reduction to Pattern B was made worse in Garment B1.

Figure 6.10 shows the performance of woven stretch fabric (D) in the garment of reduced pattern B. There is almost no change in the garment size after one hour's wear, with only small size increase in the garment marks: AB (0.2%) and A'B' (0.3%) after eight hour wearing test. This garment was further tested by a second and third repetition of 8 hour wearer trial tests. The second wearer trial was carried out a week after the first 8 hour trial in order to refresh the memories of the specified wearer on all tests. Also a week break for garment relaxation between the second and third periods of trials was allowed. The result of size change after further two trial periods is shown in Figure 6.11. It can be seen that the size growth still occurred at the same part of the garment, which is around and across the armhole line. Further growth in these size marks is up to about 0.3% in the line AB and 0.4% in the back line A'B' after three 8 hour trials. The result confirms that the garment from a reduced pattern can achieve both fit and pattern stability to the body movement if the woven stretch fabric with a certain degree of stretch ability is used. The garment was able to retain its shape without distortion after wearing.

This objective test only assesses the basic requirements in the size and shape stability of the garments after wearing. Further, appearance and comfort are evaluated.

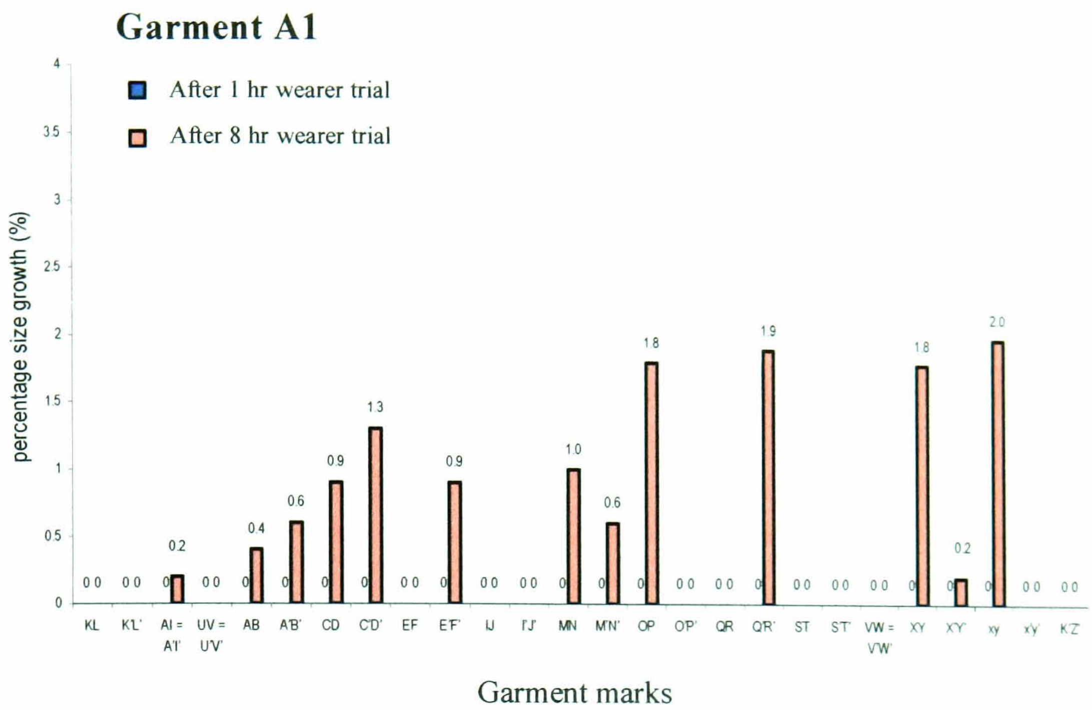


FIG. 6.6 Percentage Size growth of garment A1 within 1 hr and over an 8 hr period of wearer trial test. (where KL to K'Z' were given in page 163)

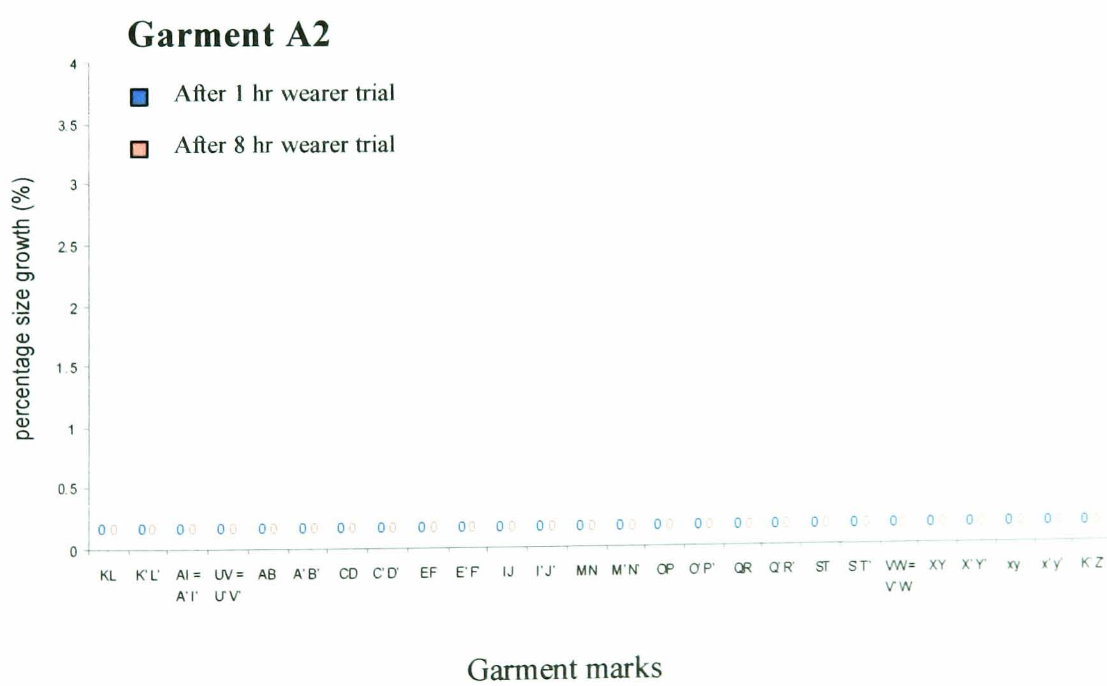


FIG. 6.7 Percentage Size growth of garment A2 within 1 hr and over an 8 hr period of wearer trial test. (where KL to K'Z' were given in page 163)

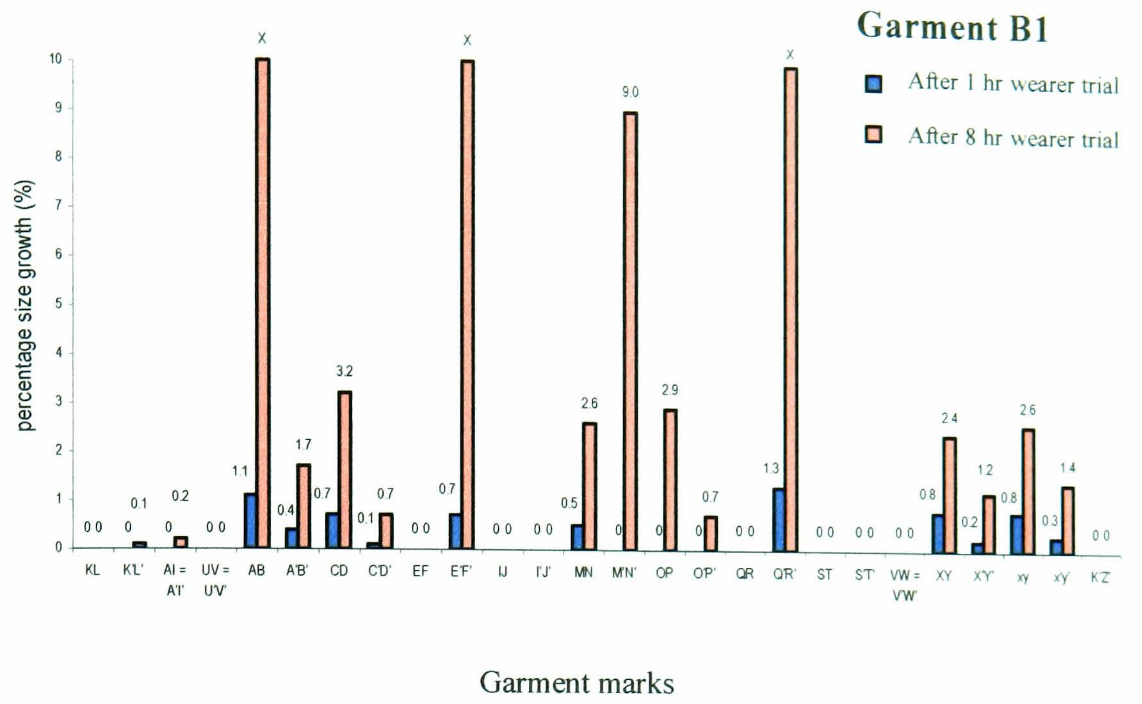


FIG. 6.8 Percentage Size growth of garment B1 within 1 hr and over an 8 hr period of wearer trial test. (where KL to K'Z' were given in page 163)

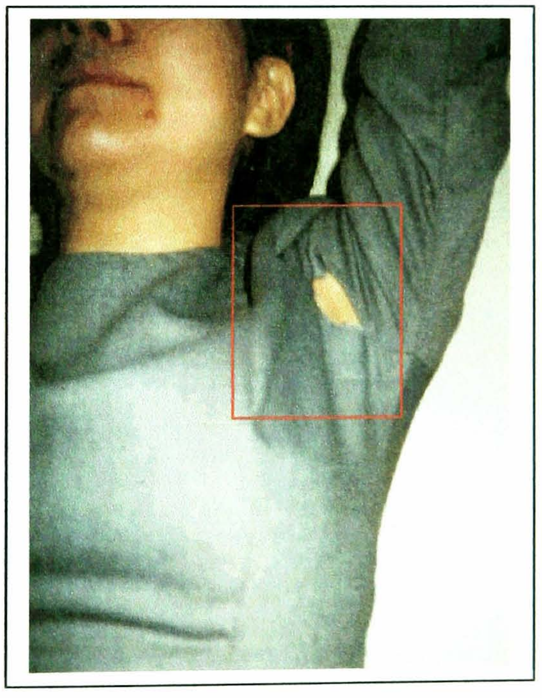


FIG 6.9 The photo of the part of the garment where garment B1 was found seam-thrown.

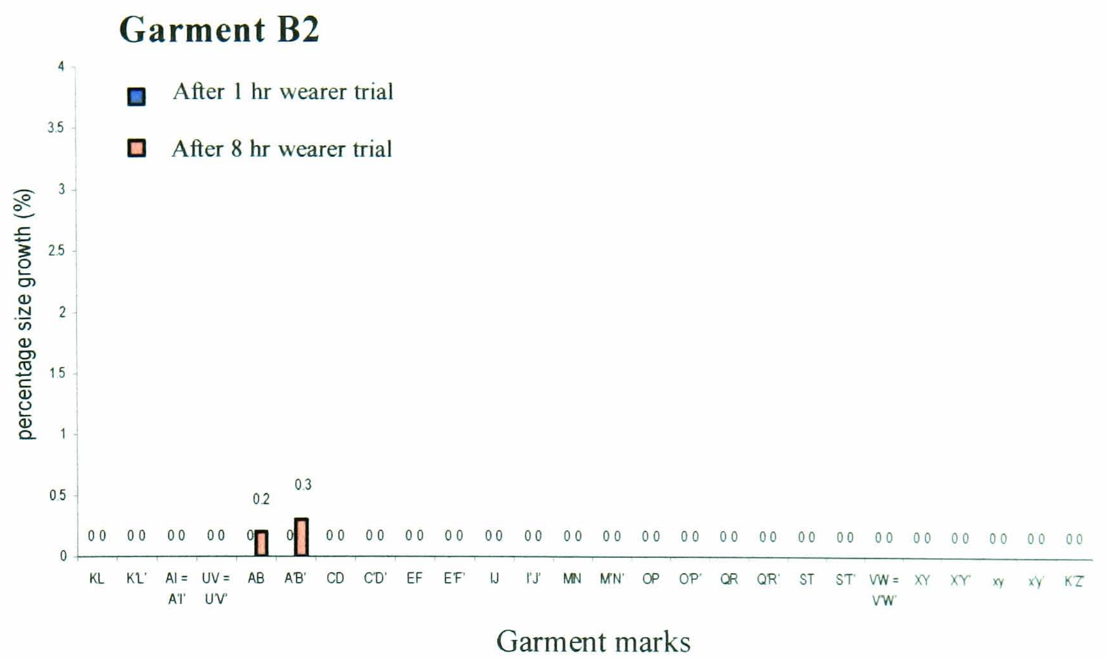


FIG. 6.10 Percentage Size growth of garment B2 within 1 hr and over an 8 hr period of wearer trial test. (where KL to K'Z' were given in page 163)

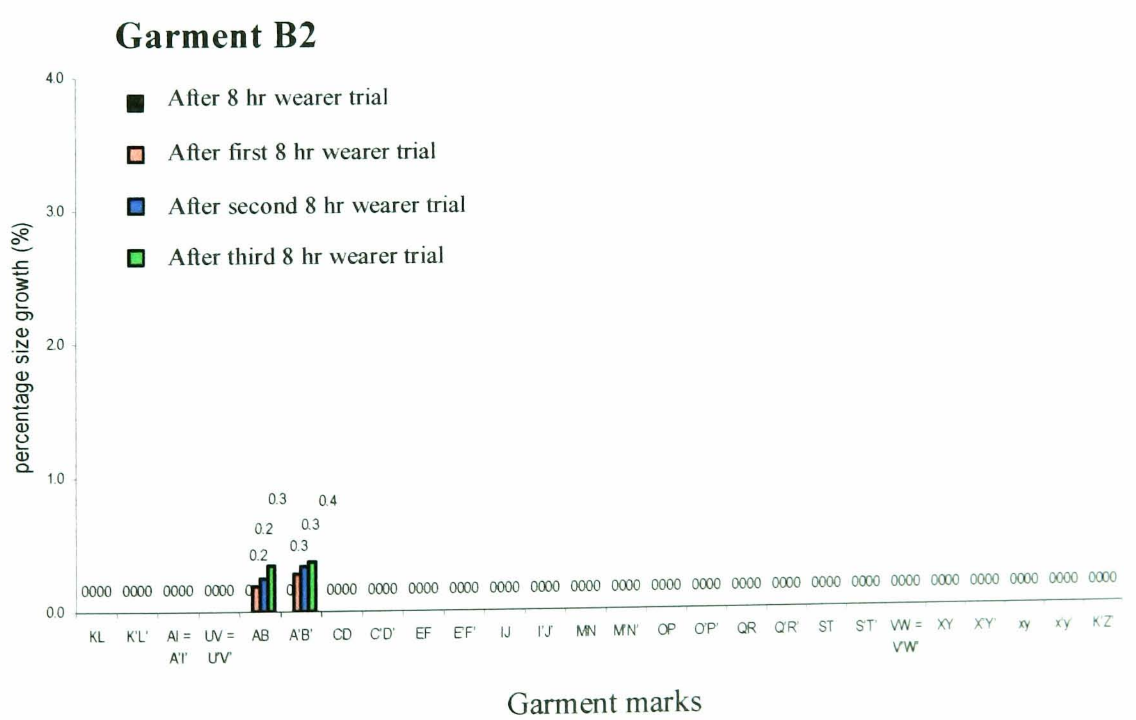


FIG. 6.11 Percentage size growth of garment B2 measured over an 8 hr wearer trial period and after 24 hrs recovery time through each test. (where KL to K'Z' were given in page 163)

6.5 Subjective Evaluation

Clothing design and manufacturers needs consistently provide both design and fit with a degree of quality, durability, ease of care, economy, and quick response. These essential aspects of apparel, fit and design are more abstract than stitch length, seam width, thread count, fibre content, fabric finish and other concrete characteristics that can be easily identified and labelled. Because of their abstract nature, fit and design are often ignored by quality control. But they must be considered. Subjective evaluation for appearance and comfort was carried out in two ways (Fig6.12). First, the wearer assessed four garments after the wearer had carried out wearer trials of these garments. The wearer had a direct feeling for comfort and satisfaction when wearing these dresses. Second, a panel of judges assessed the same four garments. The opinion from the panel of judges might be able to represent the general customers' opinion.

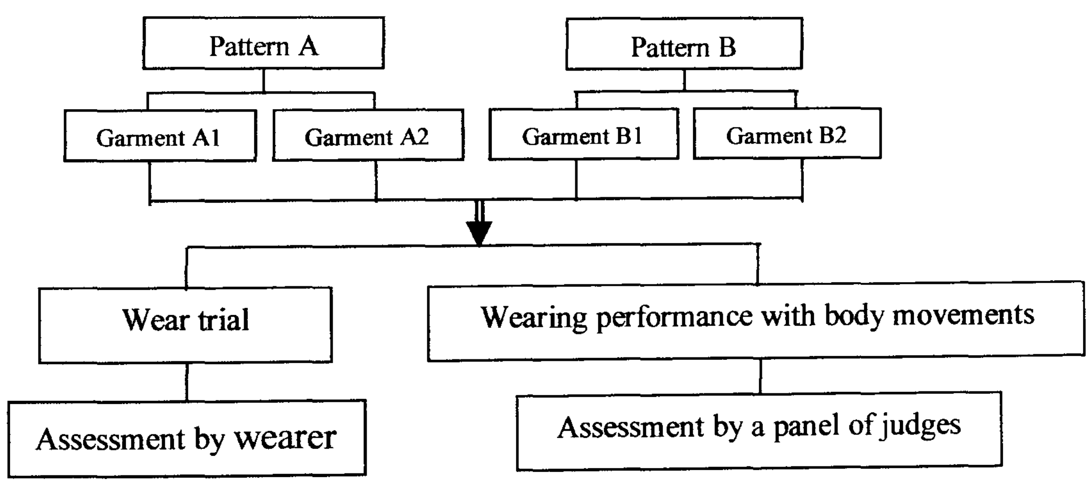


FIG. 6.12 Schematic overview of garment subjective evaluation
Pattern A is the traditional woven pattern block and pattern B is the reduced/altered woven stretch pattern block.
Garment "number 1" is made from woven fabric S and garment "number 2" made from woven stretch fabric D.

6.5.1 Assessment by Wearer

Garment design needs to satisfy the customers. Subjective evaluation by the specified wearer was a virtual wearing assessment. The wearer was asked to try on the four garments, and to comment on the comfort, shape and body fit during a long-term wearing period with natural body movement. Opinions from the wearer were of crucial important for the evaluation of the garments. The wearer was asked to rate satisfaction for the garments. Satisfaction was based on the subjective parameters such as comfort, fit, smart look, tightness, ease on wearing and appearance. The reason for liking or disliking the garment was asked to be given in detail from these parameters. For the evaluation of appearance, the wearer was asked to look at the garment in the mirror when she was wearing it. Fit was defined as the way that the garment was able to follow and show the body shape with smooth curve. If a garment can not be stretched or is very tight to the body, the wearer might not feel at ease when putting on the dress, thus ease of putting on the dress or not was included in the evaluation. Comfort is a very important parameter. The pressure on skin under a garment will make a wearer uncomfortable, when it reaches a certain degree. Restriction of body movement by the garment will also cause discomfort. The wearer describes the general feeling about these four garments as shown below.

- Garment A1: '...more comfortable (than garment B2), but could be more close fitted to the body' and '...waist can be shaped in a little bit'
- Garment A2: '...very comfortable and easy to extend body movement, but could be more close fitted to the body' and '...waist can be shaped in'
- Garment B1: '...it is a little bit tight for me, but I like the fitted shape'

• Garment B2: '...comfortable to wear and easy to extend body movement' and '...I like the fitted shape'

The wearer found that the garments made from pattern A (garments A1 and A2) were "comfortable and satisfying" at the beginning of the wear test, but after a long-term wearing period the wearer felt the garments were slightly loose. The wearer initially interpreted comfort as being "over-size or over-fit", although the garments were made and adjusted to her body shape / proportions. The trial and error method was carried out to fulfil her satisfaction criteria for comfort and fit. After the long trial period, she preferred to reduce some ease for the body shape, especially compared with the garments from pattern B. Because the wearer had never experienced in garments fitting before, it was found that her concept of ease is slightly changed with this experience.

The wearer was also fitted in garments B1 and B2 from garment pattern B which were made to the wearer's body size. Comparing only the garment shape and fit between the patterns A and B, the wearer expressed the altered garments B1 and B2 more satisfied than the garments A1 and A2.

During the wearer trial, the wearer carried out regular body movements. The questions in Table 6.4 were given to the wearer for her opinions on the performance of these four garments.

Table 6.4 Subjective assessment results given by the specified wearer

Questions	Answers			
	Garment A1	Garment A2	Garment B1	Garment B2
1. reasons to like the garment	• comfort • well fitted	• comfort • well fitted • easy to wear	• look smart	• smart look • comfort
2. reasons to dislike the garment	No	No	Feels tight	No
3. any occurrence of defect or damage	None	None	Seam-thrown	None
4. comfort feelings on the dress during wear	Comfortable	Comfortable	Uncomfortable	Comfortable
5. situation of putting the dresses on	Easy	Easy	Average	Easy
6. wear condition on the dress during wearer trial test	Smooth	Smooth	Tight	Smooth

After the wearer trials, the wearer was also asked to evaluate performance in different parts of the garments, which includes armhole, shoulder, chest, back, bust, waist and the overall appearance. The performances of the individual parts of the garments were rated based on a set of five levels: excellent, good, average, fair and poor. These five levels are defined below.

- Excellent: you noticed no change in appearance and no occurrence of defect or damage.
- Good: slight change in appearance or slight occurrence of defect but you would consider performance to be satisfactory.
- Average: the satisfaction between 'Good' and 'Fair'.
- Fair: noticeable but moderate amount of change or occurrence of defect. You are not satisfied with the defect but would find acceptable.
- Poor: considerable or marked amount of change or occurrence of a defect that you would consider being objectionable.

Tables 6.4 and 6.5 show the wearer's opinion on the performance of the garments A1, A2, B1 and B2. The results represent visual and virtual assessments of garment appearance, fit and comfort. It was found that garment B2 was shown to be the best choice, and garment A2 was the second, then garment B1 is the last choice. These four garments have two different shapes and two different fabric properties. although the garments were made upon the size measurement of the wearer and were all intended to fit her properly. It was apparent that when the woven stretch fabric D was used for making garment in pattern B, it shows significant benefits of comfort, garment shape and fit requirements.

Table 6.5 The wearer's opinions on the performance of individual parts of garments A1, A2, B1 and B2.

	Evaluation of both Fit and Comfort			
Garment Areas	Garment A1	Garment A2	Garment B1	Garment B2
Armhole	Average	Good	Average	Good
Shoulder	Average	Good	Average	Good
Chest	Average	Excellent	Poor	Excellent
Back	Average	Good	Poor	Excellent
Bust	Average	Excellent	Fair	Excellent
Waist	Average	Good	Fair	Excellent
Whole look	Good	Good	Average	Excellent

6.5.2 Assessment by A Panel of Judges

Assessment on the garments from the wearer was very valuable to understand the wearer's real feelings and comfort during the wearing, even though they are only individual opinions. However, it was also necessary to know the general criticism on the garment performance from a number of people. Therefore a panel of judges were arranged to visually assess these four garments. Forty textile fashion design students who are final year undergraduates and experienced in pattern making and design formed the panel.

The model was wearing each of the four garments (A1, A2, B1 and B2) respectively and smoothly performed the five defined postures as described in Section 5.4.2. Figure 6.13 only showed one moment of body movement during wearer's performance with four garments. The performance was recorded onto videotape and shown to the panel of judges twice. The garments were visually assessed for garment appearance and fit during movement. The forty assessors were asked to rank the garments in order of preference, considering (a) appearance and (b) visual fit during movement. The most preferred appearance and fit during movement were given a rank of 1. In turn, the least preferred appearance and fit was given a rank of 4. The rank sum for each garment was calculated by summing the ranks over all combinations for 40 assessors. The average rank for each garment was obtained as shown in Table 6.6. Analysis of variance was used to determine the statistical significance of the results (Leaf, 1987).

A1

A2

B1

B2

FIG. 6.13 Photos of the four garments assessed.

Table 6.6 Results of the subjective assessment given by 40 experienced assessors based on the two significant questions of the rank sheet (only 35 questionnaire sheets were valid for statistical analysis).

Prefer to Wear (Appearance)					**Fits to your Satisfaction (during movement)**				
Judge No.	Garment A1	Garment A2	Garment B1	Garment B2	Judge No.	Garment A1	Garment A2	Garment B1	Garment B2
1	1	3	4	2	1	2	3	4	1
2	2	1	4	3	2	3	1	4	2
3	4	2	1	3	3	4	3	1	2
4	3	4	2	1	4	3	4	2	1
5	3	4	2	1	5	3	4	2	1
6	4	2	3	1	6	4	2	3	1
7	3	4	2	1	7	4	3	1	2
8	4	3	2	1	8	4	3	2	1
9	3	4	2	1	9	4	1	3	2
10	4	2	3	1	10	3	4	2	1
11	4	3	2	1	11	4	3	2	1
12	4	3	2	1	12	1	4	3	2
13	3	4	2	1	13	3	4	2	1
14	3	4	1	2	14	4	3	1	2
15	3	4	2	1	15	3	4	2	1
16	4	3	1	2	16	1	4	3	2
17	4	3	1	2	17	4	3	1	2
18	2	3	4	1	18	2	3	4	1
19	4	3	1	2	19	4	3	1	2
20	3	2	4	1	20	3	2	4	1
21	4	2	1	3	21	4	2	1	3
22	2	1	4	3	22	4	3	1	2
23	2	3	1	4	23	2	3	1	4
24	3	4	2	1	24	4	3	2	1
25	4	3	2	1	25	2	4	3	1
26	2	4	1	3	26	2	4	1	3
27	4	1	3	2	27	4	1	3	2
28	4	3	2	1	28	3	2	4	1
29	3	4	1	2	29	1	2	3	4
30	4	1	3	2	30	4	2	3	1
31	3	4	1	2	31	4	3	2	1
32	4	3	1	2	32	4	3	1	2
33	4	1	3	2	33	4	1	3	2
34	2	3	4	1	34	2	3	4	1
35	3	4	2	1	35	4	3	2	1
Sum	113	102	76	59	**Sum**	111	100	81	58
Mean	3.23	2.91	2.17	1.69	**Mean**	3.17	2.86	2.31	1.66

Table 6.7 shows the results of averaging the ranking from 40 experienced fashion and textile designers. It is suggested that there is relatively little advantage to be gained from using stretch woven fabric whilst adopting traditional pattern procedures. And that significant advantages in appearance and fit during movement can be perceived using the developed procedure described in former chapters. It was found that

there was difference in the preferred order between Garment A2 and B1 from the wearer's opinion and the panel of judges. It could be due to different way to assess the garments. The wearer considered both appearance and comfort for ranking the garments but the panel of judges mainly relied on their visual assessment. The opinions from both the wearer and the panel of judges showed that the Garment B2 has achieved not only in garment appearance but also in the fit and comfort during the body movement. It confirms that the newly developed woven stretch pattern for woven stretch fabrics is able to meet customer needs in fit and comfort.

Table 6.7 Average rank values for the four garments

Sample	Garment A1	Garment A2	Garment B1	Garment B2
Appearance*	3.23	2.91	2.17	1.69
Fit during movement*	3.17	2.86	2.31	1.66

* Comparing with Garment A1 at the level of 0.025 with 95% confidence limits. The least significant differences are 0.40 for appearance and 0.41 for fit during movement (Leaf, 1987).

6.6 Conclusion

A new method of pattern construction has been developed to produce a reduced pattern and applied to a garment produced from woven stretch fabric of known extension and recovery properties. This garment was then assessed for appearance and fit during movement against two garments using traditional pattern construction techniques and one using the new method but produced from ordinary woven fabric. The use of the new pattern construction method was judged to be significantly better for the woven stretch fabric. The adoption of the new system could provide a reduction in time spent on pattern construction, an opportunity for increased automation by incorporating a model into pattern construction software and improved appearance for woven stretch fabric garments.

7

GENERAL CONCLUSIONS

CHAPTER 7

GENERAL CONCLUSIONS

7.1 Conclusion

The investigations were undertaken for the development of the new method for garment pattern construction for woven stretch fabrics to achieve fitting the body shape and also reserving comfort for the wearer's dynamic movements.

In order to understand the relationship between influence of stretch ability of woven stretch fabrics and garment pattern construction, a range of woven stretch fabrics and a controlled woven fabric were tested at the Instron tensile tester. Extension and recovery properties of thirteen woven stretch fabrics at the fixed load and fixed extension were determined respectively. These properties are highly dependent on the combined characteristics of fabric structure, yarn and fibre properties. It was found that the residual extension and recovery properties were influenced not only by the percentage of elastane but also the weave structure of the fabrics. A 2/2 twill fabric structure may be easier stretched than a 1/2 twill structure, but it may restrict the recovery to a small extent. There is no practical significant difference in the extension and recovery properties between plain and twill structures of woven fabrics.

From the results obtained, it was shown that the fixed load tensile test method is unsuitable for predicting fabric stretch and recovery properties of woven stretch fabrics. The fixed extension tensile test method was found to be more suitable.

In order to deal with the problem of garment distortions while a garment (fabric) is worn and is subjected to repeated body movements, the repeated tensile test was applied to simulate a wearing action. The extension and recovery of woven stretch fabrics under repeating stretch to the certain range of extensions were determined. According to their residual extensions, the acceptable extension levels for these woven stretch fabrics were obtained for the use in pattern reduction and alteration.

Pattern construction and alteration for woven stretch fabrics aimed to meet the requirement of the wearer's dynamic movements with consideration of fabric stretch and recovery properties. Five typical postures were defined to represent the range of body movement and stretch. The body sizes under different postures were determined by tape measuring and 3D body scanner. The accuracy of data obtained from the body scanner was evaluated. It was found that the size measurements from scanner/computer were very close to the data from tape measurement. But the 3D Body scanner was not able to detect some hidden body sizes of the bending postures. From the defined postures, the minimum pattern block from skin-fitted jersey garment was generated and converted to woven pattern block from skin-fitted jersey garment.

Based on a basic pattern block of shoulder-princess dress and under consideration of minimum required pattern block for body movement, the extension and recovery properties of woven stretch fabrics were taken account for pattern reduction and alteration. The garment pattern for woven stretch fabrics was generated to meet not only a fitter silhouette of a garment but also better comfort for body movement. The degree of pattern reduction and alteration for woven stretch fabrics was highly dependent upon the individual fabric level of extension and recovery properties. The new generated pattern method can also be used for the woven stretch fabrics with different extension and recovery properties by altering the boundary of the pattern.

The new method of pattern construction has been used to produce a reduced pattern and this has been applied to a garment produced from woven stretch fabric of known extension and recovery properties. This garment was then assessed for appearance and fit during movement against two garments using traditional pattern construction techniques and one using the new method but produced from ordinary woven fabric. The use of the new pattern construction method was objectively and subjectively judged for fit, appearance and comfort during the body movement.

The wearer trial was carried out for the assessment of the garment performance. The effect of body movement on garment deformation and fabric distortion was investigated. The results gave detail of information on the size and shape stability of the garments after wearing. It was confirmed that the garment from the reduced and altered pattern could achieve pattern stability to the body movement due to the certain degree of stretch and recovery properties of woven stretch fabric used. After the long period of wearer trial, wearer also felt that garment restrictions in a well fitted woven stretch garment can be significantly reduced by using woven stretch fabrics.

This garment was then assessed by a panel of judges for appearance and fit during movement against two garments using traditional pattern construction techniques and one using the new method but produced from ordinary woven fabric. The use of the new pattern construction method was judged to be significantly better for the woven stretch fabric.

Therefore the garment pattern can be predicated and produced according to the extension and recovery properties of fabrics rather than doing repeated garment sampling and wear test process (try and error). The adoption of the new pattern construction system could provide a reduction in time spent on pattern construction, an opportunity for increased automation by incorporating a model into pattern construction software and improved appearance for woven stretch fabric garments.

7.2 Recommendations for Further Research

An interesting project would be to try to find a simple test method, which could be employed by clothing companies to provide the required extension properties of fabrics. This would require extensive testing of simple methods and parameters which would correlate to an acceptable degree with Instron results.

It would be valuable to work closely with companies producing pattern design software to incorporate the model in algorithm form into the software. This would enable the automatic alteration to block dimensions in the warp and weft directions.

There is tremendous scope for further work in the area of visual assessment of apparel. As mass customisation becomes more and more popular it will be more important for the clothing industry to understand how garments are perceived by the consumer.

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